With the Author's Compl[iments]

PHOSPHATES

IN

NUTRITION,

AND

THE MINERAL THEORY OF CONSUMPTION AND ALLIED DISEASES.

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PREFACE.

In the following pages I have tried to show the importance of certain inorganic materials in the food, and their functions in the tissues. If my views are correct, as I believe them to be, a novel explanation is offered as to the cause of certain organic diseases, hitherto but little understood. With the knowledge of the cause, the rational treatment presents itself, not only as preventive, but probably also for the successful treatment of many cases of these diseases in their early stages.

The conclusions arrived at as to the dual composition of the arterioles, or capillaries, and the important part tissue phosphate plays in their nutrition, are the result of experiments undertaken in the first instance to ascertain the use of phosphoric acid in animal and vegetable life. I had no theory on the subject, so that the conclusions have arisen from, and grown with, my investigations. I have not worked to try and prove a case; but have kept a record of a series of experiments, which I subsequently tried to interpret.

I lay great stress upon the evidence of the urine, as strongly corroborative of my views of capillary metamorphosis. The constant presence in the urine of man of all the inorganic materials which enter into capillary formation, present as strong proof to my mind of mineral metamorphosis, as urea does of albuminoid metamorphosis. Both the mineral and nitrogenous compounds of urine are products of tissue destruction; and a knowledge of the composition of the different tissues enables us to gauge the waste taking place in each tissue.

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PHOSPHATES IN NUTRITION.

CHAPTER I.

APPLICATION OF CHEMISTRY TO THE INVESTIGATION OF CAUSES OF DISEASES.

Chemistry has at all times, since men began to have any ideas of this science, been of material help in the treatment of disease.

In the days of the old alchemists, absurd expectations were held as to its future probable influence on life; as the phenomena and changes wrought under their hands were noticed, ideas were entertained that it would furnish means for prolonging or perpetuating life in eternal youth, by the discovery of some new agent which would arrest decay. To this imaginary substance the term vital principle was applied, and men spent their lives in searching after the phantom. Now that a knowledge of the laws of Chemistry and its sister science Physiology has taught us the fallacy of such views, we can pity the misdirected energy of these old students, in their endeavours to discover that which, according to the laws of nature, could not exist. Our pity should however be mingled with gratitude for acting as the pioneers in a science which has conferred great benefits on mankind, that have not yet reached their limit, as every year is adding to our store of utility in its application. Although powerless to provide us with perpetual youth or prolong life beyond the allotted time, by the means originally sought after, Chemistry may yet be made to minister in many ways towards the maintenance of life, by lessening, remedying, or preventing disease, so that in course of time the old expectations formed as to its power may be to some extent realised.

A study of the chemical changes that food undergoes in the system in health, for conversion into tissue and for nutrition, aided by the knowledge of the composition of the tissues and of food, and of the laws which govern health, will help to ward off disease by observance of the laws regulating health, and in case of sickness help towards recovery by pointing out the cause of disease. Disease of every kind has its origin in some interference with the natural laws governing the body in health. Supposing these laws were not interfered with or obstructed in any way by the present generation, and that our ancestors had been equally careful, disease, except of the acute or accidental type, would be unknown, and but for these exceptions we should die but of one complaint, old age. All the zymotic diseases which at present materially increase the death rate, would be stamped out if the laws of Hygiene were generally and individually observed, under a well-conceived and properly-executed system of state supervision. To bring about such a result, Government, through properly appointed officers, would have to take care that our food was good and unadulterated, that we were sufficiently supplied with good water, that the atmosphere was uncontaminated with noxious vapours from factories, and that our sewers effectually did their work; individually we should have to pay due attention to regular exercise and living, and provide against the evils arising from sudden changes of temperature: observing in our own persons the rules of health which the law cannot be expected to supervise, but which must of necessity be left to individual discretion.

At present this millenium gives no promise of immediate advent, for our habits—congregated together as we are in villages, towns, and cities, and dependent upon a general appreciation of Hygiene—prevent such a result. Our sewers are often the means of conveying poisonous gases into our houses, being constructed by builders as much for afferent as efferent purposes, while leakage into the soil is often the means of water contamination. These act as some of the causes producing disease dependent upon present neglect of the laws of health, whilst past neglect is shown in hereditary diseases, where the sins of the fathers are visited upon the children; so that, although in theory, disease ought not to exist, except to a limited extent, and that dependent upon mechanical causes, yet as a matter of fact we shall always have it; but the extent may be materially lessened by a more general knowledge of the laws of health, and supervision for enforcing these laws.

The treatment of disease is facilitated by a knowledge of its cause; not that this of necessity leads to its cure, for the cause may be beyond our reach. Even in cases where cure is impossible, a knowledge of the cause is useful as helping to distinguish them from curable cases, and in the great majority of cases must put us in a better position for grappling with disease, and, if practicable, by avoiding in future the cause, prevent a recurrence of the disease.

The cause of disease may be ascertained by noticing the conditions which give rise to the disease, as has been done in the zymotic diseases, or by studying the phenomena which accompany the disease and characterise it, as in the inflammatory diseases. The recognition of disease in any part requires a knowledge of the appearance and condition of that part when in health. The pathologist who investigates the alterations in the different tissues produced by disease, has gained the knowledge which fits him for his work by a study of their structure and uses in health. During the last few years, the microscope has aided materially in increasing this knowledge, and by revealing the minute anatomy of organs has thrown great light on their functions; thus rendering the treatment of disease more methodical. As the revelations of the microscope have already added greatly to medical knowledge, so also chemistry is destined in the next few years to play an equally important part in explaining phenomena which are at present obscure. Minute anatomy shows the structural arrangement of the tissues, and points out the means by which different organs perform their functions in health, and the alterations in structure produced by disease. Chemistry is capable of showing the component materials of tissue, and the value of different kinds of food for special nutrition, as well as the changes in composition that insufficient or improper food produces in the various tissues.

That, up to the present time, chemistry has only acted an humble part in the investigations as to the cause and treatment of disease, is readily explained by the fact, that hitherto analytical chemistry has been acquired only by a few, who as a rule pursued their work in a direction apart or distinct from physiology. Now that chemistry is more generally taken up by the medical profession, and as more attention is paid to quantitative analysis, and new and more perfect methods of analysis are introduced, results will be obtained, which in the past have been unattainable.

Recent examinations of the inorganic materials in the soft tissues and their relative quantities, have led me to conclude that these substances exert a very important influence in nutrition; and that their absence or presence in insufficient quantities, either from diminished supply or imperfect assimilation, is the origin of a class of disease (organic) which have hitherto received no explanation as to cause.

That my views, involving as they do doctrines entirely new, and carrying so large an issue as the curability of organic diseases, will be at once generally accepted, is more than I can expect; but I am willing to trust to time and to practical results in treatment to test their truth. Up to the present time treatment based on the conclusions arrived at, has in my hands met with remarkable success.

In considering the effect of food in the production of disease, a general classification of disease is necessary, in order to eliminate from the list those diseases which have their origin from causes independent of nutrition. A classification of disease based on cause, putting together diseases which have the same or an analogous origin, may be arranged under three divisions:—

Class I.—Accidental or Inflammatory Diseases.

Class II.—Zymotic Diseases and Blood Poisons.

Class III.—Diseases from Errors of Nutrition.

Functional derangements and diseases depending upon nervous influence are not included in this list. These cannot be explained as arising from mere physical causes but depend more upon vital influence, that mysterious force whose actions we can only study and admire, but cannot in the present state of knowledge fathom or explain. In some of these, as science progresses, it will probably be found that nutrition plays an important part. As the chemical composition of the brain and nervous matter is more clearly understood, and the materials that enter into their special formation is better made out than at present, then possibly we shall be able to treat diseased conditions which are at present beyond our control, with method and success.

Referring to the classification, under the first head may be included all inflammatory and acute diseases, local or general, which arise from changes of temperature, exposure, or other agencies, uncomplicated by blood poisoning. All diseases also which depend upon mechanical agencies. As illustrations of diseases coming under this head may be mentioned—

Meningitis	Pericarditis	Pleurisy	Coughs and Colds
Brain Softening	Endocarditis	Peritonitis	Febricula
Apoplexy	Pneumonia	Enteritis	Gangrene
Sunstroke	Bronchitis	Impaction	Mortification

Inflammations of special organs, injuries and their consequences. In all these the cause of disease is interference with the circulation or mechanical injury to tissue. The symptoms, and the course and consequences, may be and are very different in these different diseases, but the gravity of the case depends upon the nature and importance to life of the organs or parts attacked, as well as upon the degree to which the inflammation reaches, or the amount of tissue injury received. By subduing inflammation, and aiding to restore injured tissue, these diseases get well. There is no inherent tendency to progressive increase in the disease, as in the organic diseases, but the natural tendency is towards recovery. Chemical investigation as to the origin and progress of these diseases is needless, as their cause and symptoms can be understood and explained by mechanical agencies and the laws which regulate the circulation.

In the second class (zymotic diseases) the phenomena are different. In these there is evidence of a morbid action in the blood, producing a train of symptoms varying with the specific nature of the poison, and characteristic of the disease. They arise, generally, from some neglect of sanitary rules, such as the accumulation of garbage or decomposing matter near overcrowded and ill-ventilated dwellings, or from the contamination of drinking water, or from eating unwholesome and poisonous food. When once generated, all the zymotic diseases have the power of reproduction under suitable and favourable conditions to an extraordinary extent. The generating cause may be introduced into the blood from the air, by inhalation through the lungs (infection); by absorption through the skin (contagion); or may be taken in the food and absorbed through the coats of the stomach (digestion).

The commonest forms of disease under this head are typhus and typhoid fevers, scarlet fever, small pox, measles, and chicken pox in this country, and cholera and the plague abroad. Whether Chemistry will be able to point out the exact character and composition of the agencies producing these diseases is at present only a matter of conjecture and speculation. The particular atom, germ, or matter which sets up the symptoms characterising the disease has never yet been separated or recognised, so that its character may be determined.

Many interesting and useful facts connected with the origin of these diseases have however been made out by noticing conditions which produce some of these diseases. The plague is at present unknown in this country. Its disappearance took place when men left off herding together in ill-ventilated and badly constructed dwellings, in the midst of garbage and rotting refuse of all kinds. Where these conditions exist, as in the cities of the East, the plague still appears. Typhus fever, which a few years ago was common in England, is now rarely seen; its disappearance has been caused by improvements in drainage, and greater cleanliness in and around dwellings; but in the Sister Isle, where the adoption of improved sanitary arrangements has been slower, typhus fever still prevails. The general introduction of the drainage system into our dwellings, has, however, through the mistakes of builders and architects, been followed by the prevalence of typhoid fever. This is essentially a disease of sewer gas; imperfections in the arrangement and construction of sewers allow the escape of sewer gas into the atmosphere of dwellings, poisoning the inmates. With perfect sewers and traps typhoid fever would be stamped out. As illustrating the origin of typhoid fever and its dependence on sewer gas there is an interesting case on record. In the island of St. Helena typhoid fever was unknown until some few years ago, when the authorities determined to sewer Jamestown, the capital. This was done, and followed by an outbreak of typhoid fever, which raged with considerable violence.

Liebig's theory is that which is generally received as explaining the phenomena of these diseases. Attempts are being made to offer different explanations of the changes that take place in the system during the attack of zymotic diseases. The advocates of any new doctrines will, however, find it difficult to found any new theory which explains as clearly as Liebig's theory does, the action of these blood poisons.

Liebig's theory likens the phenomena of these diseases to the phenomena of fermentation. As yeast added to certain substances produces, under suitable conditions, fermentation, so also the specific germ of infection is supposed to set up in the blood actions analogous to those produced by yeast in fermentable substances. Without going into the question of whether this be the true theory of action or not, there are certain symptoms and characteristics of these diseases which are common to them all, and are sufficiently well marked to allow of their being classified, and to show that they all obey the same laws. Vaccination affords a good illustration, and one open to all, of noticing the way in which diseases of the zymotic class affect the system. A specific matter, vaccine lymph, is introduced into the blood, and for a period of four or five days no effects are produced. After the expiration of about this time slight feverish symptoms occur, followed shortly by the formation of vesicles at the sites of puncture. These vesicles in due time are filled with material identical in composition with the lymph originally used, and possessing the same powers of reproduction. The infinitesimally small quantity originally introduced has by some action taking place through the blood, been multiplied, and reproduced many hundredfold. Yeast on wort and leaven on dough show like results. "A little leaven leaveneth the whole lump." A similar action takes place with all zymotic diseases. Some minute quantity of the infecting matter gets into the blood, in one of the ways pointed out, and after a short time—the period varying according to the nature of the disease—gives rise to the train of symptoms characteristic of the disease. In all zymotic diseases there is the period of latency, that is the time ensuing between the reception of the poison and the development of symptoms, the indications of fever showing the poisonous action on the blood, and the multiplication of the poison during the progress of the disease. The cause differs from that of the inflammatory class, for in the one case the condition can be explained by mechanical agencies, local in origin and more or less localised in effect; in the other the symptoms are developed through some morbid action of the blood, by which

"The life of all the blood is touched corruptibly."

Another feature peculiar to these diseases is the general immunity from a second attack. Cases are on record where individuals have had two or even three attacks of measles, scarlet fever, or small pox, but such cases are of rare occurrence, and not numerous enough to disprove the rule.

The tendency is towards recovery; the eruption and other symptoms which mark each disease are evidences of the means adopted for the elimination of the poison. In severe cases the virulence of the attack so alters the blood, or interferes to such an extent with the functions of life, that death may occur, but if life can be prolonged during the natural course of the disease, and no organic lesion takes place as a secondary result, recovery ensues. The cause and treatment of all diseases that can be classed under I. and II. are sufficiently well understood to allow of their being conducted to a safe termination in the great majority of cases; in no case need the patient's life be despaired of; "while there is life there is hope" may be safely taken as the motto in all these cases, and diligently acted upon to the end.

The diseases to be classed under head III., as diseases dependent upon innutrition, are:—Starvation, Fatty Degeneration, Rickets, Scrofula, Consumption, Leprosy, Cancer, and Scurvy.

Unfortunately for suffering humanity, the hopeful view expressed as to the termination of diseases classed under I. and II. cannot be entertained with respect to some of the diseases here mentioned. The mere recognition of some of them—consumption, leprosy, and cancer—often carries conviction to the patient of long-suffering, ending in death, and to the attendant, of inability to hold out any other prospect. Need this be so? Are these diseases of necessity as hopeless as we now think them to be? Have any real attempts been made in the right direction to find out the true and rational explanation of the cause or causes of these scourges? Or, if such attempts have been made, does it follow that because hitherto unsuccessful, they should for ever continue to be so? But a few years ago scurvy would have been placed in the list of fatal diseases, but now there is no disease which is so thoroughly under control.

CHAPTER II.

NUTRITION.

The healthy sustenance of animal life has a double call upon food, the nourishment of the tissues and organs of the body, and the maintenance of the normal temperature. By food, reserve or latent force is stored up in the tissues, ready to be called into use as occasion may require. Life in the animal has been likened to the action of a steam engine. As in the steam engine fuel generates steam that drives the machinery, which is regulated and kept in steady motion by the fly wheel, so in animal life, food produces tissue and heat, that perform all the actions of life, which are influenced and regulated by nervous influence. The amount of work an animal can do is dependent upon the amount of food that can be utilised in the production of force, that is in repairing tissue waste, or in the production of heat; just as the power of the steam engine depends upon the amount of fuel that can be utilised in the production of steam. But here the analogy ceases, for in the animal the whole body has to be built up out of the food, and force can only be called into play through the destruction of the tissues. Every movement and action of animal life is dependent upon consumption and reproduction of tissue. In the steam engine the consumption of a given amount of coal produces a certain amount of steam, possessing known power, which can be directly turned to account; but in man the same sort of calculation is not so readily made, on account partly of the complicated character of his food, and of the different purposes to which this food is applied. Any attempt at forming an absolutely accurate estimate of the value of different kinds of food is beset with difficulties, but fairly accurate conclusions may be arrived at. An examination of the chemical composition of the different tissues will show the materials necessary for their composition, and a quantitative determination of the different excreta will indicate the proportions in which these materials should be supplied. Practical observation and experience will also teach us how to regulate the supply of food, according to the requirements of the system.

Both organic and inorganic materials are to be found in all animal life. The different forms of organic food necessary for animal life are originally built up exclusively in the vegetable kingdom. The mineral kingdom can only be used for furnishing inorganic material, but under ordinary conditions of health it is unnecessary to go to this source of supply, as the herbivora obtain the inorganic materials necessary for their existence from the vegetable kingdom, and the carnivora from the animal. No vertebrate animal has the power of assimilating elementary matter and building up in its body the compounds that enter into tissue formation. The vegetable kingdom is the factory in which all food is made for animal life, and in the different forms of food, destined for different purposes. In different animals we find varying powers of assimilation, which differ even in the same class of animals. Amongst the mammalia, the ruminant can digest and assimilate as a hydro-carbon or heat producer, the cellulose of woody fibre, also gum and pectine, none of which can man utilize. The graminivora obtain all their food, both flesh-forming and heat-producing, from sources unavailable for carnivora. But in no case is a flesh-forming or nitrogenous compound, or a heat-producer (hydro-carbon) available for nutrition, built up in the body from materials which possessed before digestion a different chemical character. The different foods exist in the vegetable kingdom and are fabricated there and there only. Sugar, starch, gluten, albuminoids, and gelatine-yielding substances all have their origin in vegetable life. From this source the graminivora build up their tissues, and in turn yield up their tissues to the use of carnivora, and omnivorous man. In the words of Dumas, "L'animal s'assimile donc ou detruit des matières organiques toutes faites : il n'en crée donc pas."

The nitrogenous animal tissues are nourished by an albuminoid material, protein. All the varieties of flesh-forming food, animal and vegetable, contain this principle. If any of the cereals or potato be treated so as to remove the starch, and then with caustic potash, and afterwards with acetic acid, a precipitate is obtained, which is protein. Meat yields the same compound. This material, protein or albumen, is necessary for the formation of flesh or muscle, and no food which does not contain it in quantities sufficient to supply muscular and flesh waste can alone support healthy animal life. Another essential ingredient in food is the heat-giving material; this is supplied in starch, sugar, fat, or other similar chemical compound, for all these substances have nearly the same chemical composition. This requirement is also found in every life-sustaining food, for without it animal heat could not be maintained; the fire would die out for want of fuel, as it is by the conversion of the elements of these compounds into carbonic acid and water that the normal animal temperature is maintained.

In addition to these two essentials of food, flesh-formers and heat-producers, water and certain inorganic salts are necessary for tissue support. Water enters very largely into the composition of all the tissues, forming nearly three-fourths by weight of the whole body. All these different qualities in food are necessary for life support, and the withdrawal of any one of them from the food produces disease and eventually death. Life cannot be supported on albumen, without water, heat-producers, and the necessary inorganic salts; neither can it be maintained on the latter substances without nitrogenous material. Geese have been experimentally starved to death, by being fed solely on albumen, a substance very rich in flesh formers, but wanting in the other essentials of food. All the staple foods of man if carefully examined will show the presence of all these principles.

Analysis of some of the Staple Foods of Man.

PER CENT.

	Water.	Nitrogenous or flesh-forming food.	Heat-producing food.	Mineral matter and loss.
Potato	75·20	3·60	18·29	2·91
Wheat	14·50	14·40	65·20	5·90
Oats	14·20	11·20	67·19	6·60
Rice	13·70	7·80	74·70	3·80
Milk	87·02	4·48	7·90	0·60
Meat (Beef)	72·50	23·50	2·50	1·50
Cabbage	93·40	1·75	4·05	0·80

This table is adapted from "Watts's Dictionary of Chemistry," and from the "Cyclopædia of Agriculture," both recent works. The different kinds of hydro-carbons are classed together—fat, sugar, starch, &c.

Fruits also contain the essentials of food, in proportions varying greatly according to the kind, with, as a rule, a large preponderance of heat generators, in the form of sugar; that they also contain flesh formers is shown by the very common culinary operation of making jelly, for the setting of this edible is dependent on the presence of vegetable gelatine, a nitrogenous compound.

A comparison of the component parts of the different kinds of food enumerated presents points of interest; but a strict valuation of food based on these figures must be made with certain allowances, such as the condition of the food, whether easily digested and assimilated. The main characteristics of food, however, are the same under all conditions; meat is a flesh former, rice a heat producer, and any portion of mankind using either of these foods largely, must supplement its deficiencies by some other food to supply the want, or the system will suffer.

The consideration of the food best adapted for man is a matter of importance, for from his very conformation he is intended to utilize his food, and by selection to get a large amount of nourishment in a condensed form. His teeth proclaim him omnivorous, showing that both the animal and vegetable kingdoms are meant to furnish to his wants; his energy and activity calling largely for the renewal of tissue waste, are taxes upon nutrition, calling for large restitution; while his small stomach and limited power of digestion necessitate the use of food in a concentrated, nutritious, and readily-assimilated form. In infancy he is provided with natural food which combines all the essentials of food; for in milk we have typical food, that is a material calculated to supply all the wants of the system in infant life.

As my object is to draw attention more particularly to the inorganic materials of food, and their part in health and disease, I shall only allude to the general properties of food, to illustrate my subject: I can do this the more readily, inasmuch as the use of the organic portions of food, their metamorphosis into tissue and elimination after use, has been made the subject of careful study and investigation by men to whose doctrines I can add nothing new.

Moleschott has given, as a normal daily diet, nitrogenous material 130 grammes, fat 84 grammes, starch 404 grammes, salt 30 grammes, water 2,800 grammes; rendered in English weight, this means about 4½ ozs. of flesh-formers, and 15 ozs. of heat-producers, together with rather over 2 quarts of water. This estimate agrees with that given by M. Payen. As these results have been arrived at by independent analysts, and agree with practical experience, they may be taken as fairly accurate.

A comparison of this theoretical estimate with the ordinary rations of a soldier will show a close agreement between theory and practice. The full diet of a soldier in military hospital gives a fair average diet, and may be taken for examination.

Leaving out the small quantities of extras, this diet will consist of—

		Flesh-formers.		Heat-producers.
Meat, 12 ozs.......	..	2·82 ozs.	..	·30 ozs.
Bread, 16 ozs.	..	2·30 ,,	..	10·33 ,,
Potatoes, 16 ozs. ..	..	0·57 ,,	..	2·92 ,,
Sugar, 1½ ozs.	..	0·00 ,,	..	1·50 ,,
Milk, 4 ozs.	..	0·18 ,,	..	0·32 ,,
Butter, 1 oz.......	..	0·00 ,,	..	1·00 ,,
Total	..	5 87		16·37

The 16 ozs. of bread are reckoned as wheat; as bread contains more water than wheat flour, the figures given are somewhat in excess: so also with the meat, which is reckoned as muscular fibre only; if due allowance be made for these exaggerations, this diet table will as nearly as possible fulfil the necessary requirements of organic food for every day use.

According to the *Daily News* (October 14, 1877), the ration of a Turkish soldier consists of meat, 256 grammes; bread, 960 grammes; vegetables, 256 grammes; butter, 14 grammes. This would show about 6 ozs. of flesh-formers and 20 ozs. of heat-producers: a good diet, if the soldier be fortunate enough to get full allowance, and very different to the single pound of dates, which Sulieman Pacha, or some other Pacha, is reported to have boasted was all that the Turkish soldier required. The fighting qualities of any soldier on a pound of dates as his sole dietary would not be great.

As no one article of diet contains the necessary alimentary constituents in proper relative proportions, the necessity for a mixed diet becomes obvious. Substances rich in flesh-formers are poor in heat-producers, as meat for example; while substances like rice, which are full of heat-producers, have small quantities of flesh-forming material. If the dietary be restricted to one article, it becomes necessary to use large quantities of this article. The potato-eating Irishman and the rice-eating Coolie are obliged to eat large quantities of these respective substances to obtain the requisite quantity of flesh-formers. To depend upon the flesh-forming properties of potato would require the daily consumption of about 9 lbs. of potatoes. This large quantity would give a great excess of heat-generators, which would have to be eliminated, throwing unnecessary work upon that portion of the system upon which this task would devolve.

The diseases that arise from neglecting to preserve the proper balance between the varieties of food are manifold, but may be classed under two heads: the first comprising those which arise from excess; the second from insufficient supply, partial or general. Eating or drinking to excess overtaxes some part of the digestive or assimilative process, and if persisted in, leads to a breakdown from overwork; fortunately for us, the organs of the body are tolerant to a very liberal extent of abuse of this kind, and if mankind showed more judgment in preserving the proper proportions between the constituents of food, excess might be indulged in with even more impunity than it is. Excess in one way leads as a rule to privation in some other way, and the system suffers not so much from the excess as from the privation. Innutrition is a more frequent cause of disease than excess, and is more likely to produce organic disease. Take the case of a man who indulges in alcohol to excess, and whose constant potations ruin his appetite for other food; this man soon finishes his career. The flesh-formers are deficient in his blood; there is no proper material to supply muscle, and as a consequence this tissue wastes. His flesh undergoes fatty degeneration, for in lieu of the proper nitrogenous material, a hydro-carbon is made use of, because nature has not the proper material wherewith to supply his muscle waste, and makes use of such material as is at hand. The man who can indulge his taste for alcohol with comparative impunity, is the man who retains his appetite for meat. He also suffers in the end, but, as long as he continues to take his proper quantity of flesh-forming food, is less likely to get fatty degeneration of his muscular tissue, than the man whose sole food is a hydro-carbon. The formation of flesh is dependent upon the supply of nitrogenous material, and if this be wanting, true muscle cannot be formed, but only a fatty imitation of it. Many diseases, if considered in this light, although apparently arising from excess, are in reality the result of innutrition. Excess destroys the wholesome appetite for variety; there is a craving for some one article of diet which is indulged in to the exclusion of the other essential alimentary constituents.

The absence of all food produces, as every one knows, starvation; deficiency of flesh-formers, with excess of heat-generators, produces fatty degeneration; deficiency of heat-factors entails loss of temperature, or the consumption of the soft tissues, to keep up the normal temperature, and when these are burnt up—death. The absence also of the inorganic materials in food leads to well-marked diseases, which shall be presently considered.

Experience, the most efficient of all tutors, has taught men the practical application of the uses of different varieties of food. All the different nations of the world have selected as the staple national food some one or more articles which combine these essentials, and where there is any deviation to a great extent in the balance between the flesh-formers and heat-producers, it is to meet some exceptional case.

The Esquimaux consumes a large excess of heat-producers. He wants to get through a long, cold winter, with little muscular exertion, and therefore to keep up his temperature lays in a stock of fat, candles, blubber, and other such delicacies; having partaken to repletion of his hydro-carbonaceous food, he dozes away on the top of his oven until the effects of his meal are beginning to decline, when he rouses up, to lay in a fresh supply. The amount of fat consumed by the inhabitants of northern latitudes is incredible, if gauged by our own habits. These people have learnt, by practical experience, as well as science could have taught them, that in order to keep up the normal temperature of the body, they want a large supply of heat-factors. The Mexican Indian, on the other hand, who lives in constant activity, and whose muscles are in great use, wants a flesh-forming food. This he obtains by drying his meat in the sun, and living almost entirely on this. In one case we see men who take little exercise, in a cold climate, selecting as their food heat-givers, as being the food most suitable for life under their conditions of life; on the other hand we find men, living in a warm climate, where the normal temperature of the body is more easily maintained, selecting as their food dried meat, a very highly nitrogenised material, and from a chemical point of view the best adapted for their purpose, that they could have chosen.

In the table of proximate analyses of food, given a few pages back, the last column shows the per centage of mineral matter, &c., in each article of food, but does not show the composition of this mineral matter. Phosphate and carbonate of lime have been long known to form the greater portion of bone, and inorganic salts have been determined in the blood, and in the ash of the soft tissues; but their special forms and combinations in the tissues have not been clearly made out. The presence of definite salts in vegetable ash has been clearly made out by agricultural chemists, and tables have been constructed showing the prevalence of one or more of these saline compounds in different plants; on this information manures have been constructed suitable for the requirements of various plants, based on the deficiencies of the soil. Plants have been scientifically fed by an examination of their constituents, as shown by analysis of the ash, and the supply of those ingredients necessary for their growth, by manure, which an examination of the soil has shown to be deficient. The aim of the scientific agriculturist is to find out the chemical requirements, in the way of food, of the plant which he wishes to grow, and then to provide for the adequate supply of this food. Towards this end, chemistry has materially aided. Cannot the doctrines of agricultural chemistry be turned to profitable account in investigating the requirements of the different tissues for inorganic material, and ascertaining how far the different kinds of food fulfil their requirements?

CHAPTER III.

INORGANIC COMPOSITION OF THE TISSUES AND FOOD.

The different inorganic acids met with in the tissues and fluids of the body are phosphoric, sulphuric, hydrochloric, and carbonic acids. The different bases are lime, magnesia, potash, soda, and iron. This last exists in the blood. Of these different inorganic substances, phosphoric acid and lime exist in the largest quantity. Bone constitutes a large proportion of the animal frame, and is made up in the human adult of from 60 to 70 per cent. of mineral matter, and from 30 to 40 per cent. of organic matter. The organic matter consists of a nitrogenous compound which yields gelatine on prolonged boiling, and the inorganic matter consists mainly of tricalcic phosphate, a material containing three equivalents of lime to one of phosphoric acid, and in which phosphoric acid exists in the proportion of 45·81 per cent. Apart from its existence in bone, phosphoric acid is met with in nearly every tissue of the body, and as its presence is not likely to depend upon accident, but must arise from some occasion for its services, it will be well to offer some explanation for its universal presence, and of its use in different tissues.

Phosphoric acid is a combination of phosphorus and oxygen in the proportion of one equivalent of phosphorus to five of oxygen. It is the highest in the series of compounds between these two elementary bodies, the series being

Sub Oxide	P_2O
Oxide (Hypo-phosphorus acid)	PO
Phosphorus Acid..	PO_3
Phosphoric Acid	PO_5

Of these different oxides, the last (phosphoric acid) is by far the most important, as it is an essential part of both animal and vegetable life, and exists very largely in the mineral kingdom. Spain and Germany are both rich in mineral phosphates, while France and England possess large beds of coprolites.

The only form of phosphorus that I have met with in food and in the animal tissues is phosphoric acid. The protein compounds have been represented by some chemists as containing phosphorus in an elementary state, or in some other combination than phosphoric acid, but I have failed to obtain any evidence of its existence, except in the highest state of oxidation, as phosphoric acid. The errors that have led to this mistake must have arisen from imperfect manipulations, whereby the phosphoric acid has been reduced and its phosphorus estimated as free phosphorus. This is a point of importance in nutrition, especially as regards nervous matter, and I shall revert to it later on.

There are some peculiarities respecting the behaviour of phosphoric acid with bases, which have an important bearing on the state and formation of phosphates in the different animal tissues. Phosphoric acid combines with water and with bases in certain fixed multiple proportions.

There are three definite hydrates of phosphoric acid, and three definite salts. The series comprises

1st, Monobasic salts (one equiv. of acid and one of base).

2nd, Dibasic salts (two equivs. of base to one of acid).

3rd, Tribasic salts (three equivs. of base to one of acid).

It is to this last order (the tribasic) that all of the phosphates in the tissues belong; nervous tissues containing in addition phosphoric acid as a hydrate, or in combination with organic matter. The tribasic series of phosphates possesses the exceptional peculiarity, that the combination between the base and the acid need not be confined to one particular base; but by an interchange of bases, a series of salts can be produced in almost endless variety. The three equivalents of base may be built up of two, three, or more different bases, but always containing three equivalents of basic matter to one of acid. In illustration, starting with tricalcic phosphate (3 CaO, PO_5), as typical of this class of salt, there may be substituted for two equivalents of lime, one each of magnesia and soda, so as to obtain a salt with the formula, CaO, Mgo., NaO., PO_5). There are here three equivalents of base to one of acid, just as in the tricalcic compound; but in one case all the equivalents consist of lime, in the other they are made up of one each of lime, magnesia, and soda. Each of these separate bases may be again divided, and represented by an equivalent portion of some other base. These tribasic salts are insoluble in alkaline solutions, sparingly soluble in neutral, and I have obtained from different solutions of chlorides, carbonates, and phosphates, several varieties of them. The analysis of one prepared in my laboratory, dried at 212, showed per cent.:—

Lime	28
Magnesia	9
Soda	16
Phosphoric Acid	47
	100

These combinations of phosphoric acid and bases are of great importance in the formation of certain tissues, and their existence can be clearly made out in all tissues and organs which contain capillaries. This has led me to the inference that this salt is a component of arterial and capillary membrane, more especially as the inner membrane of arteries can be shown to contain it. The vascular tissues and organs, such as the skin, liver, kidney, &c., show the existence of this salt in considerable quantities; while the less vascular, such as tendon and hair, show only traces.

The animal tissues here named have yielded the following quantities of phosphoric acid:—

Tissue.	*Phosphoric Acid per cent.*
Tendon of Ox	·020
Pig Skin	·147
Kidney of Pig	·244
Brain of Pig	·589
Lung of Pig	·281
Liver of Pig	·435
Brain of Sheep	·752
Lung of Sheep	·307
Heart of Sheep (muscular fibre)	·398
Liver of Sheep	·288
Kidney of Sheep	·332
Aorta of Pig (outer coat)	·167
Aorta of Pig (inner coat)	·512
Aorta of Ox (middle coat)	·192

	Tissue.	*Phosphoric Acid per cent.*
	Aorta of Ox (inner coat)	·384
	Aorta of Ox (inner and middle coat)	·281
No. 1	Human Brain (cerebrum)	·728
No. 1	Human Brain (cerebellum)	·723
No. 1	Human Lung	·280
No. 1	Human Kidney	·327
No. 2	Human Brain (cerebrum)	·597
No. 2	Human Brain (cerebellum)	·482
No. 2	Human Kidney	·244
No. 2	Human Spleen	·244

The quantity of phosphoric acid in tendon, as compared with that in other tissues, is very small, and if we take into consideration the larger quantity of water in other soft tissues as compared to tendon, the difference becomes still more striking. As tendon is very sparingly vascular, it is a strong argument in favour of the theory, that the seat of phosphates in the tissues is in the capillaries.

The human tissues in No. 1 were from a healthy adult, killed by an accident; those in No. 2 were from a soldier, who died from Addison's disease. All the tissues were examined in their natural state, undried.

Phosphoric acid is also present in all kinds of food, animal and vegetable, except the hydro-carbons.

Article of Food.	*Phosphoric Acid per cent.*
Bread	·282
Beer	·076
Rice	·115
Lemon Juice	·032
Apple	·025
Milk	·141
Grape Juice (foreign white)	·032
Wine (Madeira)	·064

Article of Food.	*Phosphoric Acid per cent.*
Cod Liver Oil	·010
Potato	·141
Meat	·343
Diabetic Bran Biscuit	·758
Cheese	1·140
Onion	·080
Hops	1·028
Malt	·450
Liebig's *extractum carnis*	6·455
Coffee	·501
Cocoa	·990
Tea	·951
Pea (dried split)	·874
Egg	·182

This table shows the general presence of phosphoric acid in food, but is only of partial use in forming an estimate of the comparative value of food as a phosphate bearer, as the condition of the phosphoric acid, its solubility and combinations, is not shown, and some of the foods mentioned, such as tea and coffee are not eaten in their entirety, but have only a portion of their phosphates extracted by water before use. Good, well-made tea, yields up about a third of its phosphates. The substances which have a chemical reputation as condensed and nourishing foods, show, however, a large per centage of phosphoric acid. Leibig's "extractum carnis" heads the list; next comes cheese, a strong nutritious food; and close to it is the pea, the nourishing properties of which were amply tested in the Franco-German war, in the famed pea sausage.

In vegetable matter the synthesis of the compounds of phosphoric acid is a matter of great difficulty, as in many cases it exists with a variety of other acids, and with a multiplicity of bases, each of which would have to be examined and determined quantitatively to ascertain the exact combination of the phosphoric acid. Where a number of acids and bases exist, the saddle may be put upon the wrong horse—that is, the acid and base erroneously coupled and false conclusions drawn; but in the examination of animal matter this error is not likely to arise, for the number of acids and bases being limited, their correct synthesis readily presents itself.

In animal tissues, except nervous, I have always found phosphoric acid in combination with a base—that is, as a phosphate. In nervous matter there is evidence of a somewhat different condition to that which exists in the other soft tissues, the consideration of which shall follow the examination of the phosphates in soft tissues.

Lime, magnesia, potash, soda, chlorine, and phosphoric acid are to be found in all the soft tissues which contain capillaries, as the following analyses show:—

INORGANIC CONSTITUENTS OF DIFFERENT TISSUES.—*per cent.*

	Human Lung.	Sheep's Lung, No. 1.	Sheep's Lung, No. 2.	Sheep's Liver, No. 1.	Sheep's Liver, No. 2.	Sheep's Kidney.
Lime	·152 ..	·006 ..	·008 ..	·006 ..	·010 ..	·016
Magnesia ..	·224 ..	·032 ..	·021 ..	·018 ..	·036 ..	·057
Potash ..	·060 ..	·190 ..	·180 ..	·113 ..	·080 ..	·072
Soda	·094 ..	·097 ..	·579 ..	·249 ..	·180 ..	·600
Phosphoric Acid	·280 ..	·300 ..	·307 ..	·288 ..	·256 ..	·332
Chlorine ..	·070 ..	·009 ..	·560 ..	·100 ..	·080 ..	·420

	Beef.	Aorta of Ox, inner coat.	Aorta of Pig, outer coat.	Pig's Lung.	Pig's Liver.
Lime	·035	·056	·028	·024	·074
Magnesia	·032	·093	·026	·072	·108
Potash	·190	·231	·121	·180	·280
Soda	·123	·223	·130	·346	·545
Phosphoric Acid	·256	·344	·160	·281	·435
Chlorine	·120	·150	·080	·100	·020

Tissues contain, in addition to these, traces of sulphuric acid, sulphur, and iron; but as these exist in very minute quantities, and are not concerned in the formation of the salt to which I wish to draw attention, they are not shown in these analyses.

A careful examination of the table will show points of great interest, and if the analyses be compared, will help materially, to show the presence of some prevailing substance. The chlorine and soda always exist in somewhat proportionate quantities, where there is much of the one there is a correspondingly large quantity of the other. In the human lung there is little soda, ·094, and therefore little chlorine, ·070; in the kidney of sheep there is a larger quantity of soda, ·600, with also a larger quantity of chlorine, ·420. In the pig's liver there is a large quantity of soda, with only a small proportion of chlorine; this is readily accounted for by the presence of soda in the bile. The liver in this instance must have contained a small portion of bile, in the course of formation or elimination, which was analysed with the liver substance. It is obvious that in each case all the chlorine was in combination with the greater part of the sodium of soda, to form common salt, a general constituent of the blood. If the proper equivalent quantity of sodium be in each case removed from the quantity of soda given, so as to form common salt, and the remaining quantities of base and acid given, the result will be in

	Human Lung.	Sheep's Lung.	Sheep's Lung.	Sheep's Liver.	Sheep's Liver.	Sheep's Kidney.	Beef
Base	·471	·325	·299	·299	·237	·379	·276
Phospc. Acid	·280	·300	·307	·288	·256	·332	·256

	Aorta of Ox, inner coat.	Aorta of Pig, outer coat.	Lung of Pig.	Liver of Pig.
Base	·473	·235	·473	1·002
Phospc. Acid	·344	·160	·281	·435

The greater part of these materials enters into the composition of the tissue itself, and does not depend upon the presence of blood. It is true that I examined the tissues in their fresh state, and consequently in the presence of small quantities of blood, but the proportion of blood was so small in each case as not to have affected the results, except in a way which I shall point out. The proportionate quantity of these phosphatic salts in the blood, is not so large as that shown by the analyses to exist in the tissues: and there is a well-marked difference in the relative quantities of the inorganic materials. Becqueril and Rodier ("Watts's Dictionary of Chemistry," article Blood,) give as the mean composition of human blood (male):—

Chloride of Sodium	·310 per cent.
Other Soluble Salts	·250 ,,
Earthy Phosphates	·033 ,
Iron	·057 ,,

Leaving out the chloride of sodium and the iron there remain but ·250 and ·032 parts of saline matter for the formation of phosphatic salts; but as potash always exists in the blood (probably as a carbonate) the greater portion must consist of this salt, leaving a very small quantity, which can be represented as a phosphate.

My analysis of pig's blood shows :—

Lime	·020	per cent.
Magnesia	·054	,,
Potash	·260	,,
Soda..	·150	,,
Phosphoric Acid	·115	,,

Chlorine not determined.

Common salt is a universal constituent of blood, so that although the chlorine here was not determined, the inference is fair that the soda here represented was in combination with chlorine. After the removal of the soda, the remaining bases, or their oxides, amount to ·334, and the phosphoric acid to ·115. A larger preponderance of base, and an absolutely smaller quantity of phosphoric acid, is shown in both these analyses of blood, than any examination of tissue shows. Both in the relative proportions of bases and phosphoric acid, and in the absolute quantity, blood and tissue show a well marked difference, and as the quantity in blood is much smaller than in tissue, even weight for weight, the quantity of saline ingredients found in the tissues can only be slightly affected by the amount of blood, which they contain in the fresh state. There is enough excess of alkali in the tissues, arising from the presence of blood, to tell upon the results of the analysis, if a synthesis of the analysis be made, as I shall presently show; but with the known composition of the blood, the influence thus brought to bear upon the result, can be readily taken into account. No healthy organ or vascular tissue that I have examined, either in herbivora or omnivora, shows so small a quantity of phosphoric acid as ·115 per cent., the quantity contained in pig's blood; even this small quantity is more than is shown in Becqueril and Rodier's analysis.

The synthesis of the inorganic materials to form tissue phosphate, from the analyses given, shows different results in different classes of animals as regards the organs, but the same result as affecting the composition of the aorta. The difference in the composition of the inorganic matter in herbivora and omnivora is uniform; in omnivora the organs show a slight excess of base over the quantity required for the formation of tissue phosphate, in herbivora the excess is on the side of the phosphoric acid.

The synthesis of the organs of omnivora given before will show in—

Human Lung.			Pig's Lung.			Pig's Liver.		
Base.		PO_5 in theory.	Base.		PO_5 in theory.	Base.		PO_5 in theory.
Lime	·152	·128	Lime	·024	·020	Lime	·074	·062
Magnesia	·224	·165	Magnesia	·072	·053	Magnesia	·108	·079
Potash	·060	·030	Potash	·180	·090	Potash	·280	·141
Soda	·034	·026	Soda	·257	·197	Soda	·530	·403
		·349			·360			·685
The quantity obtained was		·280			·281			·435

This shows in each case a deficiency of phosphoric acid, or rather an excess of base over and above that required, with the existing quantity of phosphoric acid, to form triple phosphate.

The organs of herbivora show the converse—an excess of phosphoric acid for the proportion of bases.

Sheep's Lung.

Base.		PO_5 in theory.
Lime	·006	·005
Magnesia	·032	·027
Potash	·190	·096
Soda	·097	·072
		·200
The quantity obtained was		·300

Sheep's Lung.

Base.		PO_5 in theory.
Lime	·008	·006
Magnesia	·021	·015
Potash	·180	·090
Soda	·090	·070
		·191
		·307

Sheep's Liver.

Base.		PO_5 in theory.
Lime	·006	·005
Magnesia	·018	·013
Potash	·113	·061
Soda	·162	·122
		·201
		·288

Sheep's Liver.

Base.		PO_5 in theory.
Lime	·010	·007
Magnesia	·036	·029
Potash	·080	·041
Soda	·111	·084
		·161
The quantity obtained was		·256

Sheep's Kidney.

Base.		PO_5 in theory.
Lime	·016	·014
Magnesia	·057	·040
Potash	·072	·037
Soda	·233	·178
		·269
		·332

Beef, Muscular Fibre

Base.		PO_5 in theory.
Lime	·035	·029
Magnesia	·032	·023
Potash	·190	·096
Soda	·019	·015
		·163
		·256

All these syntheses show a deficiency of base for the quantity of acid; in other words, an excess of phosphoric acid.

Analysis of the Aorta shows, both in herbivora and omnivora, clear indication of tribasic phosphate without excess of either acid or base.

Aorta of Ox.

Base.		PO_5 in theory.
Lime	·056	·047
Magnesia	·093	·069
Potash	·231	·116
Soda	·093	·071
		·301
The quantity obtained was		·324

Aorta of Pig.

Base.		PO_5 in theory.
Lime	·028	·025
Magnesia	·026	·020
Potash	·121	·061
Soda	·061	·049
		·155
		·160

Aorta of Pig.

Base.		PO_5 in theory.
Lime	·016	·014
Magnesia	·046	·034
Potash	·157	·079
Soda	·050	·040
		·167
		·167

Allowing for some slight error in manipulation in the first case, we have in these last three analyses a clearly defined triple phosphate. A subsequent analysis of the aorta of ox, confirmed, as far as it was carried, those results, by yielding bases ·407 to phosphoric acid ·220 per cent.

If these results are correct—viz., that the minute chemistry of the organs shows in herbivora a deficiency of base, and in omnivora an excess—they should admit of explanation.

Liebig, in his "Organic Chemistry of Physiology and Pathology," says "A comparison of the urine of the carnivora "and graminivora shows very clearly, that the process of "metamorphosis in the tissues is different, both in form "and in rapidity, in the two classes of animals.

"The urine of carnivorous animals is acid, and contains "alkaline bases united with uric, phosphoric, and sulphuric "acids. We know perfectly the source of the two latter acids. "All the tissues, with the exception of the cellular tissue and "membrane, contain phosphoric acid and sulphur, which "latter element is converted into sulphuric acid by the "oxygen of the arterial blood. In the various fluids of the "body there are only traces of phosphates and sulphates, "except in the urine, where both are found in abundance. "It is plain that they are derived from the metamorphosed "tissues; they enter into the venous blood in the form of "soluble salts, and are separated from it in its passage "through the kidney.

"The urine of the graminivora is alkaline; it contains "alkaline carbonates in abundance, and so small a portion "of alkaline phosphates as to have been overlooked by "most observers.

"The deficiency or absence of alkaline phosphates in the "urine of the graminivora, obviously indicates the slowness "with which the tissues in this class of animals are "metamorphosed; for if we assume that a horse consumes "a quantity of vegetable fibrine and albumen corresponding "to the amount of nitrogen in his daily food (about 4½ ozs.), "and that the quantity of tissue metamorphosed is equal to "that newly-formed, then the quantity of phosphoric acid, "which on these suppositions would exist in the urine is "not so small as not to be easily detected by analysis, "in the daily secretion of urine (3lbs. according to "Boussingault); for it would amount to 0·8 per cent. But "as above stated, most observers have been unable to "detect phosphoric acid in the urine of the horse.

"Hence it is obvious, that the phosphoric acid, which in "consequence of the metamorphosis of tissues is produced "in the form of soluble alkaline phosphates, must re-enter "the circulation in this class of animals. It is there em-"ployed in forming brain and nervous matter, to which it "is essential, and also, no doubt, in contributing to the "supply of the earthy parts of the bones. It is probable, "however, that the greater part of the earth of bones is ob-"tained by the direct assimilation of phosphate of lime, "while the soluble phosphates are better adapted for the "production of nervous matter.

"In the graminivora, therefore, whose food contains so "small a proportion of phosphorus or of phosphates, the "organism collects all the soluble phosphates produced by "the metamorphosis of tissues, and employs them for the "development of the bones, and of the phosphorised con-"stituents of the brain; the organs of excretion do not "separate these salts from the blood. The phosphoric "acid, which by the change of matter is separated in the "uncombined state, is not expelled from the body as "phosphate of soda; but we find it in the solid excrements "in the form of insoluble earthy phosphates."

All my analyses of tissues confirm these views: that the herbivora eliminate alkalies in excess from the blood as soon as they are digested, as there is no requirement in the system for them, but retain the phosphoric acid for use in tissue formation. All the organs of herbivora for this reason show phosphoric acid in excess. This condition cannot depend upon any influence exerted by the nature of their food on the blood, but solely on circumstances connected immediately with tissue nutrition, and with elimination. If it depended upon food influence, the converse to existing phenomena would exist; for as the food of herbivora is eminently alkaline, with only a small proportion of phosphoric acid, we should find proportionate alkalinity on examination.

An analysis of hay shows it to contain about these quantities of bases and phosphoric acid in 100 parts:—

Lime	1·123
Magnesia	·396
Potash	1·751
Soda	3·909
Phosphoric Acid	·794

The proportion of bases to phosphoric acid here shown is as about 8 to 1, whereas the ordinary diet of man shows only a proportion of about 6 to 4. Again, as the food of man is much more concentrated than that of herbivora, and the nutrition of his tissues can consequently be carried on with a smaller quantity (allowing for difference in bulk), there is not so large an amount of useless matter to be got rid of. Man, properly and judiciously fed, takes as his daily supply the quantity of food requisite for the passing wants of the system, and in a condition approximating in chemical character the tissues to be replaced, or easily converted by oxidation into the heat-factors. His ingesta and egesta are well balanced, and the metamorphosis of one into the other can take place readily and completely.

With the herbivora the case is different. To obtain the necessary amount of nitrogenous material, the cow consumes a great quantity of grass, which contains a large proportion of useless matter; if we take into consideration the composition of grass and hay, with the amount consumed, it will be obvious that the amount of alkalies passing through the system of this animal must be very large, and that if their transit were not rapid, abundant evidence of their presence would exist in the tissues.

Reasoning by analogy would lead to the conclusion that in omnivora, an excess of alkali is required for nutrition; alkalies in excess are not in health eliminated, and analysis of the tissues shows their presence slightly in excess.

Minute chemical examination of the tissues shows to great extent the work going on in the tissues, and often points out the special secreting or eliminating functions of an organ. The liver often shows both soda and phosphoric acid in excess, doubtless dependent upon the presence of bile; and the kidney the presence of large quantities of chlorine and soda, from the elimination of urine going on. In the interpretation therefore of analyses, due allowance must in each case be made for the functions of different organs, and the probable effect upon the result.

With these requisite allowances applied to each particular case, in accordance with the nature of the requirements, there is unmistakeable evidence of the existence of triple phosphate in every organ and every vascular tissue in the body, both in carnivora and herbivora.

The presence of this salt cannot depend upon its existence in any of the proximate principles; if it did, it would be found in relative proportion to their other characteristic constituents. Sulphur is present in all albumenous tissues. The proportion of sulphur is larger in muscle than in nervous matter; being in the former case ·165 per cent., in the latter ·057, while the converse holds good as regards the evidence of phosphoric acid. Phosphoric acid exists in larger quantities in nervous matter than in muscle. Its presence cannot, therefore, depend upon albumen, neither does it depend upon gelatine or gelatine-yielding matter; for tendons contain only a faint trace of phosphates, while bone contains three-fourths of phosphates. They are both gelatine-yielding tissues, and of the two the tissue poorest in phosphate would, bulk for bulk, yield much the larger quantity of gelatine. Arterial membrane is another form of gelatine-yielding tissue containing phosphates, but in a very different form to bone. So that in these three tissues—bone, arterial membrane, and tendon—all gelatine-yielding structures, we can trace no analogy to the presence of phosphates, in any relative proportions.

The only inference to be drawn from these premises, is that the presence of tribasic phosphate in all the organs of the body is dependent on its entering into capillary formation. In nervous matter, besides this, it takes part in tissue formation, or rather phosphoric acid does, probably as a component ingredient of cerebral matter. There is great chemical analogy between bone and arterial membrane: they both contain gelatine-yielding matter, as their organic constituent, and a salt which is of the same tribasic character. In both there is a blending of the organic and inorganic materials to form a homogeneous total: in the presence of large quantities of organic matter, as in the capillaries, the mineral or inorganic portion is not so patent as in bone, where the inorganic portion predominates; but in both the presence of a tribasic phosphate salt can by analysis be clearly demonstrated. The capillaries cannot be separated from surrounding tissues, for examination; but the larger arteries can be examined, and in these I have found all the indications of the presence of tribasic phosphate. Strong confirmatory evidence of the existence of this salt in the capillaries, is given by the fact of the inner membrane showing a much larger proportion than the middle and outer membranes. It is the inner coat which is the foundation and commencement of the finer arteries, and subsequently of the capillaries; analysis, as well as pathological evidence to be afterwards adduced, show that as the arteries decrease in size, they are altered in composition by an increase in the proportion of inorganic to organic material. The aorta of the pig, in one analysis, showed in its thin internal sheath phosphoric acid amounting to ·512 per cent., while the same aorta in its middle tunic showed only ·160 per cent.; so also the aorta of the ox showed in its outer coat ·192 per cent., and ·384 per cent. in the inner.

The quantity of inorganic material in the tissues may appear at first sight to be too small to play any important part in nutrition. A careful survey of the facts will show the fallacy of this view. The analysis of human lung shows ·280 per cent. of phosphoric acid and ·470 of bases, a total of ·750, nearly all of which exists as tribasic phosphate. Human soft tissues contain about 70 per cent. of water; the remaining solid matter contains therefore in 30 parts ·750 of inorganic material. The proportion of solids forming capillaries and that forming the remainder of the organ cannot be ascertained; but supposing the capillary substance to constitute one-third of the total solids, the result would give ·750 of inorganic matter to 10 of capillary, that is 7½ per cent. This is a quantity quite large enough to exert considerable influence on the formation of capillaries, and if the proportion of capillary solids to other solids be taken at a lower figure than one-third, the relative quantity of inorganic material will be larger even than this. The deduction is based on the conclusion that all the inorganic matter of the soft tissues exists in the capillaries, which I believe to be the case, except as regards nervous tissue, which offers exceptional features.

In recent examinations of tissue, I have, where practicable, injected the blood vessels with distilled water, so as to wash away all extraneous matter dependent upon the presence of blood or of eliminated or secreted matter. The material left after treatment by copious syringing through the whole vascular system, and washing, can only consist of such substances as enter directly into tissue composition. The formation and existence of tissue phosphate is by this method rendered more distinct than if an organ be examined in its original condition.

CHAPTER IV.

PHOSPHORIC ACID AND PHOSPHATES IN NERVOUS TISSUE.

The inorganic constituents of brain and nerve present features distinct to those apparent in the other soft tissues, for although they all contain the same inorganic materials —lime, magnesia, potash, soda, chlorine, and phosphoric acid—there is a large excess of phosphoric acid in the brain of both omnivora and herbivora.

An analysis of apparently healthy brain showed per cent. (cerebrum):—

Lime..	·185
Magnesia	·082
Potash	·197
Soda	·187
Phosphoric Acid	·728

Chlorine was not determined. If the total of the bases be compared with the total of the bases in human lung previously given, the soda in each case being left out as being in great part combined with chlorine, a great similarity will be noticed as to the proportion of base in each case. I have also noticed the same feature in examining the brain and other organs of the same individual in the lower animals. At times a much larger quantity of base is to be found, but when this is the case, there is a concomitant increase of some other element or acid to account for the extra quantity of the base. In all cases, whether it be brain, lung, liver, or any other highly vascular organ, there is about the same quantity of base available for triple phosphate formation; in the less vascular tissues the quantity is smaller. The lime, magnesia, and potash in this analysis amount to ·464 per cent.; the lung of the same individual yielded ·436 per cent. When, however, the quantity of phosphoric acid is noticed, it is obvious that there is a large excess; for the quantity of base given would only require ·316 of phosphoric acid, whereas the quantity obtained was ·728. More than half the acid must exist, therefore, in some other combination than triple phosphate.

In treating of the minute chemistry of the tissues, it is more satisfactory to be able to draw conclusions from examinations on the human subject, but when the comparative study has been carried to such a point as to show the analogy between man and the lower animals, these latter may be made use of to furnish accurate information. Deductions as to tissue formation in health are more likely to be trustworthy when derived from examinations of the lower animals, and compared as occasion may serve with examinations of man, inasmuch as the inquirer can have but few opportunities of examining the human body in health, whereas the tissues of the animals used by man as food, and killed while in health, are always at his disposal.

The brain of the calf, sheep, and pig, &c., possesses the same chemical characters, and has, as far as the phenomena connected with the mere sustenance of life are concerned, the same functions as the brain of man. Increased intellect may reasonably be expected to bring about increase in structural development; of this there is evidence in the brain of man as compared with the lower animals, for the brain of man shows greater vascularity, by an increased percentage of phosphates, than the brain of the lower animals, and is of much greater bulk.

The brain of calf shows per cent. :—

Lime..	·095
Magnesia	·072
*Potash and Soda	·183
Phosphoric Acid	·665
Sulphuric Acid	·096
Sulphur	·057

* Nearly all potash.

There is here the same indication of excess of acid to base as in the analysis of human brain given. Supposing that the whole of the base were in combination with phosphoric acid to form tribasic phosphate, there would be an excess of acid of ·405. This is as nearly as possible the same proportionate excess of acid as shown in human brain. The total quantity of phosphoric acid was greater in human brain than in calf brain, but the bases were also in larger quantity; if the whole of the bases in both cases be taken as entering into capillary formation, with the equivalent proportion of phosphoric acid, the remainder in each case amounts to the same proportion per cent. of cerebral matter. This leads naturally to the conclusion, that in cerebral tissue there are all the same indications of the existence of inorganic matter, entering into capillary formation, as are shown to exist in the other tissues; but that in cerebral tissue there is, besides, a considerable per centage of phosphoric acid as a component part of this special tissue.

Cerebral matter consists of water, a nitrogenous material, fatty matter, and inorganic substances. The water needs no comment, as it is a component of all soft tissues, but the nitrogenous and fatty matter have no analogue in any other tissue. In analyses of the brain, these are generally rendered separately; but they are in reality blended together, so as to form a homogeneous tissue—a peculiar nitrogenous fat, which has no parallel. Brain matter readily softens under alkaline influence. Is not the presence of an extra quantity of phosphoric acid necessary to give the proper consistence to this tissue, to enable it to perform its proper functions? The indications of brain matter to litmus are at first generally neutral, sometimes acid, but an acid reaction is always quickly developed on boiling. By this means phosphoric acid appears to be separated from its combination, which is probably of a feeble character, but strong enough to mask, or render latent, the existing acidity, until the application of heat destroys, in a measure, this combination.

Some few months since I examined the brain of a soldier, who died of Addison's disease. Preceding death, he had well-marked symptoms of cerebral congestion, the immediate cause of death. The *post-mortem* examination showed great congestion of all the blood-vessels within the cranium, and distinct brain-softening, which was more marked in the cerebellum than in the cerebrum. Both were examined for phosphoric acid. The cerebrum yielded ·597 per cent., and the cerebellum only ·482 per cent. Healthy human brain showed ·728 per cent. The difference between these numbers indicates that the loss in the cerebellum of a quantity of phosphoric acid, equal to about

·246 per cent., reduced the healthy consistency of the brain to a softened, pulpy mass, unfit to originate or transmit any of the impressions belonging to its functions.

There is a prevalent notion that phosphorus, in an elementary state, or in some low form of oxidation, is a component of nervous matter, and objection may be taken by the believers in this theory, to these views respecting the presence and use of phosphoric acid in the brain. I have failed to detect phosphorus in an elementary state, or in any other form than that of phosphoric acid, in any tissue of the animal kingdom. Sulphur exists in an elementary state, or as a sulphide, in all protein compounds, but not phosphorus; and the analysts who have erred in pronouncing phosphorus to be a part of protein, have overlooked the universal prevalence of phosphoric acid in vascular animal tissue, and have in the course of their manipulations reduced phosphoric acid to phosphorus. To obtain a precipitate of protein from a caustic solution of any animal tissue, which shall be quite free from phosphoric acid, is not an easy matter. The albuminous precipitate cannot, without great difficulty, be washed so as to free it from adhering phosphoric acid.

To ascertain whether my method of examining tissues, by low incineration, oxidised phosphorus, thus producing phosphoric acid, which did not previously exist, I varied the method of analysis. Two equal portions by weight of sheep's brain were taken; one portion was treated with caustic potash, and warmed over a water bath until the brain matter was dissolved; hydrochloric acid was then added in excess, to separate albumen and dissolve phosphates; filtered, and the filtrate examined for phosphoric and sulphuric acids. This gave the amount of the two acids originally in the portion examined. The other portion was treated with solution of caustic potash and permanganate, evaporated to dryness over a sand bath and then fired at low red heat; the residue was treated with weak hydrochloric acid, filtered, and filtrate examined as before. The differences in the quantities of phosphoric and sulphuric acids, in the two results, would show the amount of phosphorus and sulphur that had undergone oxidation:—

The results were:—

	PO_5 per cent.	SO_3 per cent.
No. 1. Sheep's brain treated with caustic potash and acid	·864	·06
No. 2. Sheep's brain treated with permanganate and fired	·848	·153

Twenty-five grammes was in each case the quantity taken, and the results actually obtained were—in No. 1, phosphoric acid, ·216; in No. 2, phosphoric acid, 212; a difference only of ·004, that is only such as may fairly arise from unavoidable errors of manipulation. The oxidation of the sulphur is very apparent, and the efficacy of permanganate of potash as an oxidising agent, is well shown by the difference in the amount of sulphuric acid before and after treatment, for before treatment there was only ·06 per cent. of sulphuric acid, and after treatment, ·153 per cent.; the quantity of phosphoric acid was not altered, because the whole of the phosphorus was originally in the highest state of oxidation, viz., as phosphoric acid. This brain, therefore, contained no phosphorus, except as phosphoric acid, but it contained ·058 per cent. of sulphur.

Another experiment on the brain of a calf showed in—

	PO_5 per cent.	SO_3 per cent.
No. 1. Treated with alkali and then with acid	·622	·096
No. 2. Treated with permanganate and fired	·665	·240

In this case a small quantity of phosphates must have been left adhering to the albuminous precipitate obtained in No. 1, and thus lost and not reckoned in the filtrate; but putting this on one side and taking the results as here represented, the difference in the quantity of phosphoric acid is very slight, only amounting in the quantities taken (25 grammes) to the difference between ·155 and ·165, or ·010. That the differences are owing to error is shown by the fact that in the first experiment the excess is with the alkali and acid treatment, and in the second experiment is on the other side. In both cases the amount of sulphur is as nearly as possible the same—in the sheep's brain ·058, in the brain of the calf ·057 per cent.

Cheese also showed the same result:—

	PO_5 per cent.	SO_3 per cent.
No. 1. Treated with alkali and then with acid	1·60	·00
No. 2. Treated with permanganate and fired	1·66	1·05

This shows sulphur to the extent of ·042 per cent., and no phosphorus.

The large quantity of phosphoric acid in cheese may lead to the conclusion that this acid is a constituent of caseine; this I doubt. Milk always contains phosphates in certain quantities, in a state of suspension: as the caseine coagulates under the influence of rennett, or any other agent, it entangles and retains these phosphates, which remain incorporated with the cheese. In the same way the presence of fat may be accounted for, without looking upon it as a component part of caseine.

The small quantity of sulphuric acid found in brain, may be looked upon as formed by the oxidation of the sulphur contained in nervous matter, and as evidence of the constant metamorphosis of tissue going on during life. Life has in these cases ceased before elimination was completed. The constant presence of sulphuric acid in the urine, shows its production and elimination to be continual.

The other albuminous tissues give similar results; some, as muscle and hair, show more sulphur than brain, and less phosphoric acid. Hair contains only a faint trace of phosphoric acid, but a large quantity of sulphur, ·165 per cent., nearly three times the quantity that brain shows.

The examination of hair and tendon is interesting, as showing very clearly that phosphoric acid is not necessarily a constituent of nitrogenous tissues. The analyses of hair showed respectively—in No. 1, goat hair, 1·23 per cent. of sulphur; in No. 2, horse hair, 2·02 per cent.; and in No. 3, human hair, 1·59 per cent. In neither case was there evidence of phosphoric acid before or after permanganate treatment.

This additional evidence is strongly corroborative of the views expressed as to capillary formation. Hair, which contains a large proportion of nitrogenous matter, shows no phosphates, for the reason that it is devoid of capillaries.

Tendon also, a tissue rich in nitrogen, is devoid of both phosphates and capillaries, or rather contains them in very small quantities. In every tissue—whether composed of albumen, gelatine, or hydro-carbon—phosphates exist, provided that capillaries be present (phosphates exist in fat in proportion to its vascularity); but in no case do phosphates exist in any of the tissues if capillaries be absent. The only exception to this is to be found in bone, where tricalcic phosphate forms the chief part of the structure, independently of any part that phosphates play in capillary formation. Wherever phosphoric acid exists in the tissues there is evidence of bases in such proportion as to form tribasic phosphate; in bone the salt formed is tricalcic phosphate; in every other vascular tissue an analagous salt, tribasic or tissue phosphate, exists. In nervous tissue, in addition to this salt, there is evidence of the existence of an excess of phosphoric acid.

Sulphur is evidently a component part of all azotised tissues, for it exists in all these tissues without reference to their vascularity, and in proportion to the amount of nitrogen that they contain. Brain contains albumen, with a large quantity of water and considerable proportion of fatty matter; the albumen is therefore largely diluted, and as a consequence we find sulphur in small quantities. Muscle, in which the albumen is less diluted than in brain, shows a larger proportion of sulphur; and hair, which is a still more concentrated compound of nitrogen than either brain or muscle, shows a much larger proportion of sulphur. In hair, probably, a portion of the sulphur enters into combination with iron, or takes some part in producing colour; but, making allowance for this, there is still a large excess of sulphur as a constituent of the nitrogenous matter.

Looking at the fact that these two substances, phosphoric acid and sulphur, show no relative amount to each other in the tissues, and that in some of the nitrogenous tissues phosphoric acid is absent, it is obvious that they must have independent duties—they cannot be component parts of the same tissues; if they were they would exist in regular and definite proportions, which is not the case, for hair, the richest in sulphur, of the tissues, contains no phosphoric acid.

The different functions of phosphoric acid and sulphur in tissue formation is a matter of considerable importance in interpreting the readings of a quantitative examination of the constituents of the urine. I have tried to show that they are not associated in the same work, in order to indicate later on how analyses of the urine favour my view of capillary formation.

Chloride of sodium exists in small quantities in nearly all vascular tissue. The inorganic matter found on analysis of the aorta reveals the presence of chloride of sodium. It is a general constituent of the blood, but it is a difficult matter to assign its special position in tissue formation. I am inclined to look upon its presence in the different tissues as in part accidental, dependent upon the method in which, probably, tribasic phosphate is formed in the system. In the laboratory, when obtaining a precipitate of tribasic phosphate from any solution in the presence of a chloride, I have always found some portion of the chloride entangled and incorporated with the precipitate. The inorganic compounds found in the body show impurities of formation.

Bone does not consist of a chemically pure tricalcic phosphate, but contains magnesia and iron, and other foreign substances, which appear to have been accidentally introduced with the tricalcic phosphate. The presence of salt in the blood, and consequently in fresh tissue, in part accounts for its existence ; but, apart from this, it is to be found in tissues—such as the inner membrane of the aorta—which contain no blood, and must therefore be incorporated with the tissue.

Iron exists in considerable quantity in the blood, but takes no part in tissue composition.

The chemical composition of different parts of food, its separation into nitrogenous portion, into a hydro-carbon of some form, starch, sugar, or fat, and into its inorganic matter, shows on comparison with the various tissues, identity of chemical character. The entire process of nutrition in the living animal shows assimilation of suitable material for special purposes ; certain parts of food feed certain tissues ; the albuminous matter forms flesh, the gelatinous matter forms membrane, cartilage, &c. ; the inorganic substances enter into bone and capillary nutrition, and the hydrocarbons enter into fat formation, and supply combustible matter to keep up and regulate the normal temperature.

All substances necessary for healthy nutrition exist in the food ; there is no fabrication of tissues from elementary matter going on in the body, and the limits of change which can take place are tolerably well defined by our present knowledge. Protein or albumen—a compound consisting of certain definite proportions of carbon, nitrogen, hydrogen, and oxygen, with a small quantity of sulphur—supplies flesh ; the albumen of food and muscle are identical in chemical composition; this albumen or protein can also be turned to account in the nutrition of cartilage, membrane, or other gelatine-yielding tissue, because albumen can in the system be converted into gelatine, for this change comes within the recognised series of changes produced by oxidation; the converse cannot take place, a gelatine compound cannot be used for the healthy nutrition of muscle, for the chemical changes which take place in the body would not convert gelatine into albumen. These changes are referable to oxidation, and follow a regular series, which as far as the body is concerned, terminate in the elimination of the nitrogenous compound as urea. There is no retrograde movement in the series; the conversion, therefore, of protein into gelatine can take place, because this action falls within the regular series; but the conversion of gelatine into protein implies a retrograde movement which cannot take place.

CHAPTER V.

PHOSPHATES IN FOOD.

As there is an intimate connection between the chemical character of different parts of food, and of the tissues, all food which is properly calculated to sustain life ought to contain all the essentials necessary for tissue-formation and waste. This has been shown to be the case as far as regards flesh-formers and heat-producers, for all the staple foods of man contain nitrogenous matter in quantities sufficient for flesh nutrition, and at the same time a due supply of heat-producers; under certain conditions of life, particularly in this climate and with our usual habits, these different essentials of food are best obtained on a mixed diet. The existence of certain inorganic materials in the tissues has been pointed out, and if these are necessities of nutrition, they should exist in the food with as much constancy as either flesh-formers or heat-producers. That such is the case can be clearly shown.

An examination of any of the foods that take part in tissue formation or nourishment, whether of animal or vegetable origin, will show the presence of phosphoric acid; and all that I have examined for the purpose show in addition the existence of lime, magnesia, potash, and soda.

Milk may be taken as typical food, inasmuch as it is meant in early life to supply all the requirements of tissue formation and growth, and heat-production.

Two analyses of the inorganic matter in milk showed :—

	Grammes in 100 c.c. No. 1.	No. 2.
Lime	·078	·049
Magnesia	·028	·021
Potash	·039	·261
Soda	·465	
Phosphoric Acid	·196	·083
Chlorine	·150	·140

No. 2 gave a smaller quantity of saline matter in every particular than No. 1. Two samples examined for sulphur showed respectively ·014 and ·022 per cent. of sulphur. In both these analyses, there are the same inorganic substances as in the tissues, and if the quantity consumed by the young animal, for whose use it is intended, be taken into consideration, there is patent evidence that these salts are intended for nutrition. In a growing animal, bone development proceeds with rapidity; this process requires phosphate of lime, as bones contain this salt in large quantities. The quantity of bone phosphate which milk can yield must of necessity be regulated by the quantities of lime and phosphoric acid; a glance at these tables will show that only a portion of the phosphoric acid present can in these cases be used for bone growth. Supposing the whole of the lime were converted into bone phosphate, the quantity of lime given in No. 1, viz. ·078 parts in 100, would only require about ·07 parts of phosphoric acid, the quantity present being ·196; only one-third of the acid present can be utilized for bone, and two-thirds are evidently destined for some other purpose. The same results are shown in No. 2. Is not the remainder of the phosphoric acid intended to form, with the bases, tribasic phosphate for capillary formation, and phosphoric acid for nerve supply. Assuming it to be so, it may appear improbable that the quantity of tissue phosphate required for tissue nutrition should exceed that of bone phosphate required for bone development. But the differences of metamorphoses which regulate these different tissues, the hard and soft tissues, must not be lost sight of. Bone grows, but undergoes destruction or waste very slowly, there is only very sparing elimination of bone; the soft tissues grow, and are destroyed and renewed continually as long as life lasts. My investigationshave shown a larger percentage of lime in the capillaries of full-grown animals than in the young of the same species; leading to the inference, that as age advances and bone development stops, lime is not required for bone growth, and is then used up in the capillaries.

In addition to inorganic matter (identical in character to that found in the tissues), milk contains all the other essentials of food—caseine for flesh formation, butter and sugar as heat-generators. In healthy milk the different constituents exist in proper proportions for the nourishment of the young for whose use it is intended: the organic portion is all required and made use of. Is it not a fair inference that all the inorganic matter has also its proper function and destination?

Other kinds of food furnish similar evidence. The diet table already quoted would show the following results:—

TABLE SHOWING LIME, MAGNESIA, &c., CONSUMED ON DIET NAMED.

Article of Food and quantity.	Lime in Grammes.	Magnesia in Grammes.	Potash in Grammes.	Soda in Grammes.	Phosphoric Acid in Grammes.
Meat, 12oz...	·115	·112	·687	·367	1·088
Bread, 18oz.	·102	·214	·714	·275	1·683
Potatoes, 16oz.	·146	·266	1·523	·159	·545
Milk, 6oz.	·146	·042	·041	·173	·246
Vegetables, 4oz.	·124	·041	·423	·077	·114
Total	·633	·675	3·388	1·051	3·676

In addition to these, the other inorganic materials would be chlorine and sulphuric acid. In such a diet as this, the chlorine, not reckoning any common salt as taken with the food, would be about ·70 parts of a gramme, while the sulphuric acid would be in very small quantity. This last exists very sparingly in food, and the small quantities that do exist are rendered still smaller by the process of cooking. Sulphur also exists in the flesh-forming portion of all these foods, meat containing about ·160 per cent., and flour ·120 per cent. of this substance. In potato there is a small quantity of organic acid and carbonic acid, both in combination with a portion of the bases. If we allow for this, and also the amount of sodium to be deducted from the soda, as representing salt, there will be left bases and phosphoric acid, in about the proper proportion to form tribasic phosphate. I am not implying that this phosphatic salt actually exists ready formed in food for the purposes of nutrition; but that the materials are at hand, and that in the process of assimilation they can be made to assume the requisite character.

A portion of phosphates taken in food takes no part in nutrition, as they are voided in an insoluble form in the *fœces.* The proportion used in nutrition can be fairly guaged by an examination of the urine under different conditions of diet and exercise. Under ordinary conditions this method of examination and deduction can only approximate the truth; to be absolutely correct it would be necessary to carry out a lengthened series of analyses, conducted under strict dietary, and regulated exercise. For all practical purposes the information to be thus gained is, however, accurate.

The phosphoric acid in *fæces* amounts to about ·75 parts of a gramme daily. In estimating the value of any dietary as phosphate bearing, this quantity must therefore be deducted, as being insoluble and taking no part in nutrition.

CHAPTER VI.

INORGANIC CONSTITUENTS OF URINE.

The urine gives valuable information respecting the amount of metamorphosis of tissue taking place in the organism, but whether it can be taken as the actual index of the amount of tissue waste or consumption, is a point open to some controversy. Is it necessary that all the urea found in the urine must have arisen from oxidation of organised flesh? May not urea be produced by oxidation of plasma in the blood before its organisation and conversion into animal tissue? Liebig in his work on organic chemistry and physiology, p. 144, says: "There can be "no greater contradiction with regard to the nutritive "process than to suppose that the nitrogen of the food "can pass into the urine as urea, without having pre-"viously become part of an organised tissue; for albumen, "the only constituent of the blood which from its amount "ought to be taken into consideration, suffers not the "slightest change in passing through the liver or kidneys. "We find it in every part of the body with the same appear-"ance and the same properties. These organs cannot be "adapted for the alteration or decomposition of the "substance from which all the other organs are to be "formed." This statement is conveyed in plain, emphatic language, and comes from a high authority, but notwithstanding is open to objection and contradiction. There is no evidence that the blood, in passing through the liver and kidneys, is not altered; on the contrary, there is every reason to suppose that alterations in the composition of the blood do take place in its transit through the capillaries of these organs; the liver secretes bile by abstraction of certain materials from the blood, and the kidneys secrete urea and phosphates as well as other products which are abstracted from the same source. Whether these products are the result of metamorphosis of tissue, or changes brought about in the food by the process of digestion, provided that the same chemical substance is produced, must be a matter of indifference to the secreting organ. The mere organisation of fibrin or albumen, and its actual conversion into living muscle, is not an absolute necessity for the formation of urea, for this compound can be produced in the laboratory from cyanate of ammonium. The experiments recorded by Bidder and Schmidt show that a certain portion of urea is dependent on tissue metamorphosis. Animals were kept without food for 18 days, and the urea daily estimated. The quantity of urea was found to be nearly the same, except on the first two and last two days. On the first two days the animals gave indications, evidently affected by food previously taken, of an increased amount of urea; on the last two the animals were dying, and elimination as a matter of course ceasing, causing a diminution in the quantity of urea. On the intervening days the excretion of urea must have represented tissue metamorphosis. On feeding cats differently, with varying quantities of flesh, the amount of urea was found to be largely influenced by the amount of food, so that when the animals were fed on large quantities of flesh the amount of urea was far in excess of that required for normal metamorphosis.

Are we to suppose that in exhausting disease, accompanied with high temperature, such as fever, where there is a large development of urea, and low vitality, that there is such increased energy in the tissues as to keep up supply and demand equally, through their agency? That the organism is under the influence of excessive oxidation, the high temperature and rapid pulse show; but to allow that all the urea eliminated in such cases arose alone from destruction of organised tissue would imply either the existence of an immense amount of nitrogenous tissue, which we know cannot exist, or powers of reproducing tissue in obedience to the call for consumption, which in the impaired state of assimilation would be impossible.

"It is almost certain that if an amount of nitrogenous "food greater than is required by the wants of the "system be taken, the excess beeomes converted into urea, "and is eliminated by the kidneys." *(Todd and Bowman's Physiology).* The rational treatment of fevers consists in giving nitrogenous and hydro-carbonaceous food in an easily digested form, so as to save tissue combustion.

The same train of reasoning applies to the inorganic constituents of urine. I have found different foods and medicines alter the urine in a way which could not have depended upon tissue change, and instances are common enough of the presence in the urine of substances alien to nutrition.

The composition of the urine cannot therefore be taken alone, as affording exact evidence of the quantitative metamorphosis of tissue. On the other hand its examination, properly conducted with fair inferences, may materially help towards forming right conclusions, as to the quantitative elimination of material which has served for tissue nutrition. As indicating the character of the different materials used in tissue formation, and the products that arise from destruction of certain tissues, its evidence is quite conclusive, as it is the great channel for the elimination of used up matter, and shows strikingly the effects of metamorphosis. In the subsequent consideration of urine, I propose disregarding the presence of urea, and other nitrogenous products, as foreign to my inquiry, and confining my remarks to its inorganic constituents.

Urine contains the same inorganic materials which have been shown to exist in the tissues. Phosphoric acid varies in quantity on different diets, and is influenced by various conditions. Dr. Thudicum, in his "Pathology of the Urine," quotes the results of the examinations of different observers, as to the average quantity passed in 24 hours. According to this author

Breed	gives	as the average of	4	individuals	5·180 to	3·765	grammes
Winter	,,	,,	3	,,		4·36	,,
Morber	,,	,,	2	,,		3·05	,,
Neubauer	,,	,,	2	,,		2·35	,,
Aubert	,,	,,	2	,,		2·80	,,
					Total average	3·66	

An increase in the activity of the secreting work of the kidney leads generally to an increase in the quantity of phosphates; circumstances which favour an increase in the quantity of urea and sulphuric acid, as a rule, also increase the quantity of phosphoric acid, but this is liable to variations and is by no means a rule without exceptions.

I have found the urine to furnish the same evidence of the independent function of phosphoric acid, as compared with sulphuric acid, as is shown to exist by chemical examination of the different tissues which yield these acids. Where, however, there is a strain on all the eliminating organs of the body, such as occurs in well fed and hardly worked individuals in health, then we get evidence of extra tissue consumption, in an increased quantity of both phosphoric and sulphuric acids.

Three separate analyses of the urine of a healthy adult made at intervals of about a month, showed respectively 2·95 grammes, 2·88 grammes, and 1·728 grammes of phosphoric acid as passed in 24 hours, thus giving as my average about 2·5 grammes. Many articles of food materially increase the quantity of phosphoric acid voided in the urine. An invalid, fed on milk alone, passed 5·5 grammes of phosphoric acid in his urine; beer, also, must have the effect of increasing the secretion of this acid, as phosphoric acid exists in appreciable quantities in beer. Phosphoric acid arising from such sources as this can take no part in nutrition; in order to arrive at anything like an accurate estimate of the quantity of phosphoric acid taking part in nutrition, these sources of error should be avoided. In my examinations, I selected for experiment individuals living regularly on plain diet, such as that analysed in the table given, and drinking no beer, or liquids which could materially increase the amount of phosphoric acid. My object was to obtain a fair idea of the elimination of the inorganic materials from an examination of the urine, removing all causes likely to mislead, in considering these materials as representing tissue waste.

The following are two analyses of the inorganic constituents of healthy urine :—

Total Urine passed in 24 Hours, contained in

		No. 1.	No. 2.
Lime	grammes	·495	·855
Magnesia	,,	·674	·300
Potash	,,	2·020	·750
Soda	,,	4·830	4·815
Phosphoric Acid	,,	1·728	2·880
Chlorine	,,	6·300	4·500
Sulphuric Acid	,,	2·230	3·135

These agree with analyses given by Dr. Parkes, Dr. Miller, and others, making due allowance for the fact that as the urine is influenced by various agencies, of food, amount and character of work, &c., there must be a difference in the results.

As my interpretation of the synthesis of these products differs materially from that generally given, let me point out why I have been led to question the accuracy of the views hitherto held.

Chlorides.—As regards the combinations into which chlorine enters, I have nothing to add to the received opinion that chlorine in the urine exists in combination with sodium, as common salt, derived principally from the food—sometimes also as chloride of potassium. There is evidence of chloride of sodium in nearly all the tissues, as a component part of their structure (this has been already shown). Some of the chloride of sodium in urine is derived from this source by disintegration, but the quantity contributed from this source must be small as compared with that which food yields.

Sulphuric Acid.—This acid owes its presence in the urine in part to the oxidation of nitrogenous tissue, and is in part derived from the food; the quantity, however, from this last source is under ordinary circumstances of health and diet very small. Is it free, or is it combined with a base? As it exists in the urine it is probably, owing to its strong affinity to the bases present, in combination as a sulphate; but originally all that portion which is derived from tissue oxidation, is at the time of its formation certainly free acid, for the nitrogenous tissues contain bases which are already in combination with phosphoric acid, as tribasic phosphate. The test for sulphuric acid is very accurate and reliable, allowing very small quantities to be detected, and by this, the presence of very small quantities in the tissues is revealed. All the azotised tissues show sulphuric acid, but only in such quantities as may be accounted for, by arrest of life taking place in the act of elimination. Beef showed ·04 per cent. of sulphuric acid, brain ·06 and ·096 in two instances, a portion even of this small amount having been probably created by the oxidation of the sulphur, in albumen, as the result of incineration. Ordinary food contains only infinitesimal quantities of sulphuric acid or sulphates, so that the source of supply for this compound in the urine must be very small. Flour contains practically no sulphates; I have failed to obtain any but the faintest traces in wheaten flour. In the published analyses of the ash of cereals, sulphuric acid is given as one of the constituents of ash of wheat, but as the ash examined is obtained generally by long continued heat, it is probable that the greater part of the sulphuric acid represented is manufactured, during calcination, by the oxidation of the sulphur in the flesh-formers of wheat. Even supposing that my conclusions on this point are wrong, the error does not materially affect my argument: the published analyses of wheat (average of 32 analyses), as given in the "Cyclopoedia of Agriculture," show 0·33 per cent. of sulphuric acid in the ash, the per centage of ash being 1·67. This would only show ·005 per cent. of sulphuric acid in flour, a quantity too small for consideration. Potatoes and some other vegetables contain sulphates in larger quantities than this, but the fact that these are eaten after they have been boiled must not be lost sight of; this effects the removal of the greater portion of the soluble sulphates, and the insoluble would be voided without undergoing assimilation. The quantity of meat in the diet table (12 ozs.) would only show ·136 parts of a gramme of sulphuric acid. In milk I have failed at times to detect sulphuric acid, at other times have obtained small quantities. Some authors assert that milk contains no sulphuric acid in the fresh state. All staple foods show the absence of sulphuric acid or sulphates, or the presence in such small quantities as to lead to the conclusion that the sulphuric acid in urine can owe its presence in very small measure, if at all, to the influence of food.

Sulphur is a component of all azotised tissues; these by their destruction yield nitrogenous products, such as urea, by the oxidation of their albuminoid portion, and sulphuric acid by the oxidation of their sulphur.

Some years ago Dr. Bence Jones showed that the sulphates (for sulphates, ought not the reading to be sulphuric acid?) were increased during the incessant muscular action of chorea, and in delirium tremens; at the same time there was a corresponding increase in the amount of urea. This shows that excessive destruction of both muscle and nerve leads to an increase in the products which result from the oxidation of these tissues, the sulphur of both muscle and nerve is converted into sulphuric acid, and the nitrogenous portion is converted into urea, so that the formation of urea and sulphuric acid may be supposed to proceed with even step and side by side. That this is the case I have no doubt, although up to the present time it has not been conclusively proved. Deductions drawn from examinations of the urine are liable to sources of error, for the actual secretion (or rather excretion, for this it is that guides us) is not necessarily a guage of actual metamorphosis, for the tissue oxidation may take place, and the elimination from the blood of these products of oxidation may from various causes be delayed. Experiments conducted with the view of deciding these phenomena of nutrition have been too hurried, cause and effect have been expected to follow with immediate results. The experiments of Fick and Wislicenus, as recently given in the supplement to Watt's "Dictionary of Chemistry" (article Nutrition, page 875), are illustrations of my meaning. These gentlemen underwent great muscular exertion for eight hours in the ascent of a Swiss mountain, and examined their urine for urea as a test of muscle waste, before, during the ascent, and after. The conclusions arrived at were, that the exercise did not perceptibly increase muscle waste, because the amount of urea during the ascent was not perceptibly increased in the urine.

I cannot but look upon this as erroneous.

The phenomena of nutrition are carried on smoothly and quietly, not by fits and starts. The blood is the carrier of all the materials required for nutrition, and also of matter intended for elimination. Both ingesta and egesta circulate indiscriminately in this medium, and it is the function of certain organs to separate either the one or the other from the blood. In the performance of these functions all the different organs are influenced by special stimulants. Certain drugs affect certain organs. Empirical medicine has taught us this, but why or wherefore remains to be shown. The mere fact of the non-excretion of certain materials is no evidence of their non-existence in the blood. An active condition of the organ, whose services we are testing, is therefore a necessity, if we wish to arrive at correct results; at the same time there ought to be the certainty that there is no compensatory agency at work, by which the work may be shared. The skin and kidneys perform to a great extent the same functions; copious perspiration leads to diminished renal secretion, this alteration in work being confined not only to the elimination of water, but of other effete material. Funke has proved the existence of urea in considerable quantities in perspiration, and it is open to further investigation, as to whether the skin and lungs may not get rid of nitrogen in other forms. Before it can be considered as proved, that exercise does not increase the elimination of nitrogen, all these possible sources of error must be guarded against; the investigation must be so carried out as to determine quantitatively not only urea, but nitrogen, and the enquiry must not be confined merely to elimination of the kidneys, but must embrace the products of respiration and perspiration. Active muscular exertion in a rareified air is just the condition which would stimulate the activity of lungs and skin, and thereby lessen the work of the kidneys.

In the absence of proof to the contrary, it may therefore be taken on the testimony of the chemical nature of the nitrogenous tissues, that their metamorphosis into compounds for elimination is accompanied by the formation of urea, or some analagous compound, and sulphuric acid.

The quantity of sulphuric acid in food is small, but the quantity of sulphur entering into the composition of its flesh-forming portion is large. The quantity of sulphur in the food and the quantity of sulphuric acid in the urine bear a very marked proportion to each other; this is especially the case where the diet is regulated to supply waste. The relationship between the ingesta and egesta of sulphur compounds can be defined with fair accuracy by examining the different articles of food for sulphur, and the urine voided, for sulphuric acid.

On an ordinary diet, the whole, or nearly the whole, of the sulphuric acid found in urine arises from oxidation of sulphur. The lime, magnesia, and potash in urine bear a proportion more or less marked to the amount of phosphoric acid present, but are not influenced by the amount of sulphuric acid. An adult, in health, taking moderate exercise, and whose food is not taken in excess, passes about 3 grammes of sulphuric acid daily in his urine. If the diet given be taken as calculated to keep up the even balance of ingesta and egesta, it will be found that the sulphur in the nitrogenous portions of the food on this diet, corresponds as nearly as possible to the amount of sulphuric acid (3 grammes).

A reference to the diet table at page XVIII. in the Appendix will show that the meat yields ·561 grammes, bread ·622 grammes; which together with potatoes, milk, and vegetables, bring the total up to 1·323 grammes of sulphur. But to produce 3 grammes of sulphuric acid, only 1·2 grammes of sulphur are required. All the determinations given in this table are slightly in excess, for the calculations are based on the examination of the articles in greater purity than is practicable in actual use. The proportion of ingredients in meat is estimated from the quantity in pure muscular fibre; again the analysis of bread is really the analysis of flour, the per centage of water in which is much less than in bread; so that with proper corrections for these errors, this diet would as nearly as possible recoup the consumption of 1·2 grammes of sulphur, arising from oxidation of the tissues to produce 3 grammes of sulphuric acid. Meat contains ·165 per cent. of sulphur; the production of 3 grammes of sulphuric acid from the oxidation of the sulphur in meat means, therefore, the destruction of 727 grammes of muscle. As other nitrogenous tissues, brain and cartilage or membrane for instance, help by their oxidation towards the supply of sulphuric acid, the whole of this loss cannot fall on muscular tissue. A comparison, however, of the quantity of muscle in the body, with the other nitrogenous tissues shows that as muscle forms the greater part of organised nitrogenous material, its destruction must furnish most of the evidence of consumption.

Sulphur is as regular an ingredient of flesh-formers as nitrogen, and in equally fixed and definite proportions; its metamorphosis produces as well marked results as the metamorphosis of nitrogen, and as sulphuric acid is more readily and accurately determined than urea, the estimation by sulphur is preferable to that by nitrogen. The results obtained by the sulphur and nitrogen plan agree very closely, for on the sulphuric scale about 170 grammes of flesh-formers in food would be required to supply the waste of 727 grammes of muscle, and the diet table framed on the nitrogen scale shows 180 grammes of flesh-formers.

This is a larger amount than is shown by chemists to be necessary for daily use; but I have slightly raised the standard both for ingesta and egesta, in all my investigations, because the conditions under which the information was collected showed more active nutrition than recognised data afford.

The quantities of sulphuric acid and phosphoric acid in the urine bear no fixed relationship to each other—sometimes one is in excess, sometimes the other; the urine of patients on milk diet, containing no sulphates, shows the usual quantity of sulphuric acid, as the accompanying analyses show.

RELATIVE QUANTITIES OF SULPHURIC AND PHOSPHORIC ACIDS PASSED BY FOUR MEN ON DIFFERENT DIETS.

	grammes in 24 hours.
No. 1.—Adult in health, on no fixed diet, with exercise.	
Phosphoric Acid	2·954
Sulphuric Acid	3·122
No. 2.—Soldier in Hospital, on Milk and extras, no exercise.	
Phosphoric Acid	2·820
Sulphuric Acid	1·276
No. 3.—Soldier in Hospital, on Milk alone, no exercise.	
Phosphoric Acid	5·100
Sulphuric Acid	2·652
No. 4.—Patient in last stage of Phthisis, no exercise.	
Phosphoric Acid	2·176
Sulphuric Acid	2·686

The largest quantity of sulphuric acid is here shown to be passed by No. 1, who was using his tissues more than the others. The excess of phosphoric acid in No. 3 must in great part have arisen from his diet, as milk is rich in phosphates; the sulphuric acid in this case must have arisen from tissue waste, as milk contains no sulphates. No. 4 shows tissue waste out of proportion to the healthy call of metamorphosis, for the patient was taking no exercise, and was so reduced by disease as only to weigh about 7 stone instead of 11, which would have been for his height, about his normal weight.

In these four cases, the amount of sulphuric acid is clearly shown to be influenced by extent of tissue waste. No. 1 shows the amount of sulphuric acid produced in a healthy man, taking exercise and doing a good deal of brain work; so that this amount may be taken as produced entirely by normal wear and tear, and would be repaired by the healthy power of reproduction. In No. 2 the quantity of phosphoric acid nearly approaches No. 1, but is clearly influenced by milk diet; the sulphuric acid shows that as he was at rest, there was no great call for consumption upon his tissues, either from exercise or from the nature of his complaint. In both 3 and 4 the temperature was high, showing that unusual combustion of tissue was taking place as the result of disease, and producing sulphuric acid in larger quantities, than tissues when at rest in health would show.

CHAPTER VII.

PHOSPHATES IN URINE.

The salts of phosphoric acid in urine are spoken of as alkaline and earthy phosphates; the former term applying to a combination of phosphoric acid with soda or potash, and the latter to combinations between the same acid and lime, or magnesia. The evidence of the existence of either of these salts in the urine as a product of metamorphosis or of elimination is extremely doubtful. Urine may be manipulated so as to lead to the formation of these salts, but the product is the result of the means employed, and is brought about by effecting interchanges of bases and acids, leading to the fabrication of new and misleading compounds. There are difficulties in showing the synthesis of the salts of phosphoric acid in a complex fluid, like the urine, particularly in the presence of such a powerful acid as sulphuric, but these difficulties are not insuperable.

The combinations between phosphoric acid and bases are various, and many of these compounds are very materially altered by heat, so that attempts to examine them after incineration can only lead to error. Altered methods of analysis may be made to obviate these sources of error. The addition of ammonia in excess to healthy urine, produces, as it is well known, a precipitate; if this be carefully examined, it will be found to consist of a true triple phosphate, identical in chemical character to that found in the capillaries of the tissues, which I have designated tissue phosphate. It is not an earthy phosphate as is generally supposed.

The following experiments will show my meaning. In the first experiment I made a complete analysis of the inorganic constituents of healthy urine, and then added liquor ammoniæ, leaving it for 24 hours to settle, and then removed precipitate by filtration. The filtered urine was then carefully examined as before; the difference would of course give the amount of material and its character precipitated by ammonia. The second experiment was conducted in the same way, except that after the first examination chalk was added, and the precipitate thus formed removed before the addition of ammonia. This in no way altered the character of the precipitate, but simply increased its quantity.

No. 1.

Bases.	Before treatment with ammonia.	After treatment. with ammonia.	Removed by filtration.
Lime	·070 ..	·00 ..	·070
Magnesia	·036 ..	·021 ..	.015
Potash and Soda ..	·656 ..	·595 ..	·061
Phosphoric Acid ..	·243 ..	·153 ..	·090
Chlorine	·520 ..	·520 ..	·000
Sulphuric Acid ..	·220 ..	·220 ..	·000

No. 2.

Bases.	After treatment with Chalk Before treatment with ammonia.	After treatment with ammonia.	Removed by filtration.
Lime	·070 ..	·00 ..	·070
Magnesia	·036 ..	.00 ..	·036
Potash and Soda ..	·656 ..	·570 . ..	·086
Phosphoric Acid ..	·243 ..	·115 ..	·128
Chlorine	·520 ..	·520 ..	·000
Sulphuric Acid ..	·190 ..	·190 ..	·000

The precipitate removed in the first was ·236, in the second ·320; showing that the presence of sulphuric acid interfered with the formation of the precipitate, as the removal of a small portion of sulphuric acid produced a more copious precipitate.

The synthesis of the bases and of the phosphoric acid removed in these two experiments is interesting, and, if compared with a theoretical compound, consisting of three equivalents of the proportion of each base to one of phosphoric acid, shows as distinctly as analyses can show that the material removed was a tribasic salt.

In the following table is shown the quantity and nature of the bases removed, and in the adjacent column the quantity of phosphoric acid, which each portion of base would theoretically require to form tribasic phosphate; at the foot of each analysis is shown the amount of phosphoric acid obtained, against that which ought theoretically to have existed:—

No. 1.

Base removed and quantity.		Quantity of PO_5 required to form tissue phosphate.
Lime ..	·070	.. .. ·059
Magnesia ..	·015	.. .. ·011
Potash ..	·061	.. .. ·030
		·100

Quantity of PO_5 obtained by analysis, ·090.

No. 2.

Base removed and quantity.		Quantity of PO_5 required to form tissue phosphate.
Lime ..	·070	.. .. ·059
Magnesia ..	·036	.. .. ·026
Potash ..	·086	.. .. ·043
		·128

Quantity of PO_5 obtained by analysis, ·128.

In No. 1, analysis showed the removal of ·090 parts of phosphoric acid, the theoretical quantity being ·100, thus showing an error of ·010.

In No. 2, the results obtained and the theoretical quantity are the same—·128 parts of phosphoric acid.

In a subsequent experiment the precipitate itself was examined, the examination being conducted in the following manner:—

A quantity of urine was examined quantitatively for sulphuric acid; having ascertained the per centage quantity of this acid, half a litre of the urine was taken, and all the sulphuric acid removed as sulphate of baryta by means of a standard solution of chloride of barium; after removal of the precipitate by filtration, the clear solution was treated with liquor ammoniæ in excess, and allowed to stand for 12 hours for precipitate to form: this was then separated and dried in a sand bath. The urine contained before treatment with ammonia 1·150 grammes of phosphoric acid, after treatment ·285 grammes in the 500 c.c. The precipitate weighed 2·86 grammes, and gave on examination the annexed composition for one gramme:—

Lime	·214
Magnesia	·074
Potash	·208
Chloride of Sodium	·068
Phosphoric Acid	·332
Organic Matter, Water, &c.	·104
	1·000

For the formation of tissue phosphate from these quantities of bases the phosphoric acid theoretically required would be—

For Lime	·214	Phosphoric Acid..	·180
,, Magnesia.. ..	·074	,, ,,	·054
,, Potash	·208	,, ,,	·104
			·338

This shows an estimated total of phosphoric acid ·338, against an obtained result of ·332. The synthesis of this analysis may be therefore expressed as—

Lime	·214	Tissue phosphate ·834	
Magnesia	·074		
Potash	·208		
Phosphoric Acid ..	·338		
Chloride of Sodium			·068
Organic Matter, Moisture, and Ammonia adhering to precipitate			·098
			1·000

By both methods—the examination of the precipitate, or the examination of the liquid before and after removal of the precipitate—the evidence afforded of the presence of this special form of triple phosphate is equally conclusive. Ammonia does not take part in the composition of the precipitate. Analysis gives no evidence of its existence in chemical combination; it simply precipitates the salt because this triple phosphate is insoluble in strongly alkaline solutions. Any other alkali has the same effect.

The removal of all the sulphuric acid from urine is shown, by this experiment, to allow of the removal of the greater part if not the whole of the bases as tissue phosphate; but the whole of the phosphoric acid present is not at the same time removed. In the experiment just described ·865 parts of a gramme were removed, and ·285 parts left. In repeated observations on the composition of the urine, I have noticed this excess of phosphoric acid. The only tissue in the human body showing excess of phosphoric acid, or rather giving evidence of the existence of free phosphoric acid, is nervous tissue. Can this excess be taken as indicating nerve waste? At times the amount of phosphoric acid in the urine is without doubt influenced by the food, but the excess is too constant to be explained in this manner, and further observations will I believe point out the connection between excess of free phosphoric acid in the urine, and brain use. In the experiment under consideration, 500 c. c. of urine showed after removal of phosphate ·285 grammes of phosphoric acid; about 1500 c. c. is the average passed by an adult in 24 hours. If the ·285 be multiplied by 3, there would be ·855 grammes of free phosphoric acid in this instance as passed by an adult in 24 hours. This coincides with other observations on the same point.

Two analyses of healthy urine have been already given. The syntheses of these will illustrate my views. In No. 1 the bases were—lime ·495, magnesia ·674, potash 1·173, requiring phosphoric acid to form tissue phosphate, 1·506; the quantity of this acid obtained was 1·728, showing an excess of ·222 in the 24 hours. In No. 2 the bases were—lime ·855, magnesia ·221, potash ·750, and soda ·885: which would require for tissue phosphate formation 1·995 parts of phosphoric acid, the quantity obtained being 2·880 or an excess of ·885 grammes in 24 hours. In Dr. Miller's analysis of healthy urine, as quoted in Todd and Bowman's Physiology, the same results appear. The quantities of bases there shown are—lime ·210, magnesia ·120, potash 1·93, and soda ·05, requiring 1·274 of phosphoric acid, with an obtained quantity of 2·120, thus giving excess of phosphoric acid ·846 grammes.

Quantitative analyses of the urine and of the tissues, show the existence of the same inorganic substances in one as in the other. The changes wrought in the compounds that exist in urine, as compared with the compounds in tissues, are as clearly the result of oxidation in the inorganic matters of nutrition, as in the organic. By consideration of the results which follow the oxidation of sulphur, and the influence that the newly-formed resulting compound, sulphuric acid, has upon the other inorganic substances, we can follow all the phenomena of inorganic metamorphosis.

All the vascular tissues show the presence of tissue phosphate; analysis of different kinds of food shows that no food which is fit for the maintenance of animal life is devoid of the inorganic materials for the supply of this salt, while examination of the urine shows its importance in the active nutrition of man by its constant presence in that secretion.

The brain shows the presence of tissue phosphate as a part of its capillary formation, and phosphoric acid in the cerebral substance in addition to the phosphate; the urine also shows free phosphoric acid as the evidence of nerve waste.

Excessive brain work leads to an apparent increase in the quantity of phosphates in the urine. Quantitative analysis can alone show whether this increase be real or only apparent; the changes wrought in the materials of inorganic nutrition by special brain work, would lead us to expect increase in both phosphates and phosphoric acid, but with a large proportion of the latter. The fact that brain work as a rule means muscle rest is obvious. Muscular exertion oxidises the sulphur, which is an integral portion of flesh, producing sulphuric acid which acts as a strong solvent of phosphates. The proportion of sulphur is much larger in muscle than in brain, so that working the latter and resting the former would materially decrease the quantity of sulphuric acid formed. The phosphates, therefore, that appear in excess after brain work, may show more prominently from a deficiency of the dissolving agent, sulphuric acid, rather than from any increase in their quantity. The relative increase of phosphoric acid from nerve use, would not be so great as the decrease of sulphuric acid from muscle rest, and sulphuric acid is a stronger solvent of phosphates than phosphoric acid. The phenomona of life depend upon tissue activity. Every movement of muscle, every thought that passes through the mind, can only take place by tissue consumption; the agents by which these changes take place, the capillaries, exposed as they are to the full influences of oxidation, must surely also be liable to the same laws of destruction and reproduction. The excessive use of any organ or tissue, must therefore produce increased capillary waste, causing an increase of phosphates in the urine; but that there is any special increase in brain use, over and above that which takes place in the use of any other vascular tissue, cannot be shown by mere superficial examination of the urine. The increase of phosphates from brain work may be apparent, owing more to deficiency of sulphuric acid, than to excess of phosphates.

CHAPTER VIII.

SPECIAL CONSIDERATIONS OF NUTRITION.

The evidence brought forward—1st, of the existence of tissue phosphate in the capillaries; 2nd, of the existence of the materials for its formation in all staple food; and 3rd, of the actual presence of the salt in the urine of man—indicates clearly the importance of this salt in nutrition. This particular compound and its functions have been strangely overlooked by both chemists and physiologists. A description even of this tribasic formation does not appear in any work on chemistry that I have had access to. Triple phosphate, that is the ammonio-magnesian phosphate, and bone phosphate (tricalcic phosphate) are well known compounds; these have an analagous chemical composition to the salt under consideration—that is they are composed of three equivalents of base to one of phosphoric acid; but there is a well-marked difference in their formation and composition in other respects. Both ammonio-magnesian and tricalcic phosphates are defined compounds consisting of regular proportions of the base in unvarying relative quantities to the acid. In tissue phosphate the relative proportion of each base can be made to vary to an endless extent, but the tribasic character of the salt in all its variations is always maintained.

A general opinion has for some time past been entertained that phosphorus, or phosphoric acid, or some other oxide of phosphorus, ministered in some way to animal nutrition; but there has been no definite explanation, or even any theory advanced as to the precise chemical composition of phosphorus or its compounds in the soft tissues.

The existence of bone phosphate in the skeleton, and of phosphoric acid or phosphates in the blood and nervous mattter was known, and the assumption formed that the presence of phosphates in the blood was dependent upon bone nutrition; in fact, that the one great use of phosphates in the blood was to supply bone, and that cerebral matter in some slight degree depended upon this phosphatic supply. A careful consideration of the evidence here adduced, cannot but convince the most sceptical that the phosphates take a far more active part in nutrition than this belief only would imply. Their constant presence in the urine of man under all conditions of food and life, is alone evidence of their general use for some purpose of vital activity. This evidence becomes stronger when we consider that their presence is not connected with bone nutrition, for bone undergoes but little waste or change in the adult. The process of bone growth goes on in the young, but is arrested in the adult. As bone acts merely a passive part in the body—serving only for the support and protection of different organs, and for the attachment of muscles—and consists mainly of inorganic materials, little liable to oxidation or alteration, it shows but slight change of substance. The metamorphosis of bone is slow, although growth of bone in the young is rapid. Quick growth does not alone lead to elimination, for this latter depends upon structural change. The well-known experiment of feeding pigs with madder to colour their bones, shows that in young growing animals the bones are quickly dyed throughout, whereas in full-grown animals the bones are more slowly coloured; in both young and old the re-absorption or disappearance of the colour is a slow process, showing sluggishness in the elimination of bone. In cases of starvation bones do not perceptibly lose weight; after death, the decay of bone takes place but slowly, compared with other tissues. The quantity of lime in the urine is also corroborative of inactivity in bone, for supposing the whole of the lime found in urine arose from bone waste, this would only show a small quantity; but the lime found in the urine does not arise from this source, for we see that it exists in tissues which exhibit active nutrition; and from the other inorganic matters which accompany it, lime in the urine is doubtless derived from capillary waste, and not from bone waste. The requirements of food have been thus far considered. The necessity of a mixed diet for man, consisting of flesh-formers, heat-producers, and inorganic matter, has been shown, and the functions of the inorganic portion indicated. Before entering into the pathology of diseases of nutrition, a glance at the laws which regulate the nutrition of different tissues, their growth and functions, will help to show why certain tissues are, in preference to others, subject to certain organic diseases, and explain some of the phenomona of these diseases.

The nutrition of different tissues is subject to varying influences; all tissues do not exhibit the same growth and development during life. Some can, under certain conditions, be increased, others show no disposition to grow or alter their size; but increased activity in health with them, leads only to increased elimination. Up to the age of puberty all tissues increase and grow, but when puberty is reached, most of them after that retain the same size. The bones of an infant are minute as compared with those of an adult, but after their full grotwh is attained remain nearly stationary. A slight structural change takes place, by an increase of inorganic matter and decrease of organic, but this takes place very slowly. The same happens with teeth. When once these have attained full growth, no perceptible change takes place, either of growth or alteration in structure, by elimination or reproduction, until decay sets in with advancing years. Osseous tissue, whether as bone or tooth, gives but little evidence of nutrient activity after puberty; in the bones of the young, and under the stimulating effects of fracture, the appropriative power in bone is great, but under no conditions of life is there evidence of any great elimination in bone. Individuals frequently show great changes in size, a thin person may become stout, or a stout person thin, but in these changes of bulk the bones of an adult take no part; they remain the same.

Hair and nails continue to grow all life long. The vigour of growth is not so great in old as in young, but the hair and nails of the old require cutting as well as those of the young. Nutrition follows laws distinct from those in other tissues; reproduction or growth is not in any way dependent upon use, for they never have any active use, nor is their growth limited by any such clear and distinct line as that drawn in respect to other tissues. Hair is influenced very greatly by race and individual characteristics. The short crisp wool of the negro, presents a very different appearance to the long tresses of a young northern belle. In hair and wool there is no absorption of their material by elimination or metamorphosis into the blood, but the destruction of these tissues follows rather the ordinary laws of decay. As hair and nails have no capillaries or absorbents, they cannot be liable to the diseases which originate in these structures; nor can any disease to which they may be liable be reproduced in other tissues of the body by absorption. The organic diseases of these tissues are limited to causes which affect directly their nutrition in whole or in part. If the nutrition be complete, hair ceases to be a part of the living being, and falls off; partial innutrition leads to changes in colour and texture. From their structure and independence of the general circulation, except for mere growth, these are the only changes that disease can produce in these structures.

Fat.—There is no tissue in the body of an adult subject to so many changes dependent upon the influences of food and habit as fat.

The general physique of man is to a great extent a matter of inheritance: the giant and pigmy are both brought into the world with the tendency towards their respective developments already implanted in them. The growth is to some extent influenced by management in early life, but as regards effects upon increase of muscle and bone there is a limit. A strong man with large muscular development can by regular exercise and judicious diet be made stronger, but a weak man with small bone and poor muscle cannot by the same means be converted into a strong man. As regards size of bone and strength of muscle, all men have congenital tendencies, they are, as it were, cast in certain moulds; but with respect to the increase of fat, the same laws do not apply. A weak man with deficient muscle cannot by food be converted into a strong muscular man; but a thin man can by suitable selection of food, and adjustment of rest and exercise, be made fat if there be healthy assimilation. The capacity to put on fat in health is general, although subjected occasionally to counteracting and disturbing influences.

In man, these disturbing influences, owing probably to his more highly developed nervous system, are often at work, but herbivorous and the lower omnivorous animals, if fed on food rich in hydro-carbons, accumulate fat. If the assimilation be in a healthy, active condition, the excess of hydro-carbon taken in the food becomes organised (converted into fat). A certain quantity is required for immediate consumption, and combustion, to keep up the normal temperature, and can be used directly for this purpose, without having undergone organisation; the excess of hydro-carbon which has undergone assimilation is stored up for possible future use in those tissues appointed for the purpose. The fattening of animals for food, under the present system of farming, and the large accumulation of fat formed periodically in hybernating animals are illustrations of fat accumulation. The mere feeding up of stock does not increase true muscle; there may be apparent increase, but analysis of the flesh would reveal the fact that the true albuminoid principle of muscle has been replaced by fat. In over-fed animals, fatty degeneration of the whole muscular tissue takes place. The same results occur in the human being, if undue quantities of hydro-carbons are persistently taken without proper exercise.

Except under certain conditions, which appear principally in man, the excreta give only slight evidence of fat elimination. The proper function of the hydro-carbons is as heat-producers; in this process they are got rid of, as carbonic acid and water by the lungs and skin, leaving no evidence of their previous existence except in the surrounding atmosphere. From its chemical character the blood cannot serve as the medium for accumulating fatty matter, for an emulsion would not circulate freely in the capillaries; the excess of fat must therefore be got rid of. There is no regular channel for its elimination, but provision is made for its accumulation. The secreting organs can clear the blood of excess of nitrogenous food and of organic matter, as shown by examination of the urine under conditions calling for increased elimination of these materials, but there is no evidence of the kidneys taking part in fat elimination. When the hydro-carbons are taken in excess, and by assimilation absorbed into the blood, where they are not wanted, and to preserve the proper character of the blood must be got rid of, there is no other way for the disposal of this excess but by conversion into fat. The areolar tissue is everywhere made use of as a store house for this excess, which is there laid by for future use. The portion so put by seems to undergo a process which presents features of organisation, inasmuch as the fat of different animals possesses characteristic features; beef suet, mutton fat, goose grease, &c., all have appearances and qualities of their own. This function of converting a hydro-carbon into another organised form of a similar compound is not confined to vertebrate animals, for bees convert sugar into wax, a substance resembling fat in some of its chemical properties.

In this case, however, the material formed is not used up as a heat-factor, nor retained in the system, but is excreted.

The formation and accumulation of fat in the human body are often productive of disease; when fat replaces nitrogenous tissue, as it can do under injudicious feeding, the fabric of the organ or tissue is changed, and under these circumstances, from its imperfect construction, can no longer perform healthy work with full activity. Fatty degeneration occurs, not so much from an excess of fat as from an absence of proper nitrogenous material to repair ordinary tissue waste. This condition differs materially from mere accumulation of fat. This last acts more mechanically than physiologically in producing disease; the large quantities of fat produced impede the different organs and interfere with their proper action, but the healthy structure still remains. Remove the superfluous fat by attention to diet, and all the train of uncomfortable symptoms disappear. In these cases chemistry can be turned to good account, by showing the proper amount of heat-producing food required under given conditions, and pointing out the proper articles of diet for use. A dietary based on chemical investigation can be established, which shall produce a sufficiency without excess of heat factors, and help gradually to restore the disturbed balance between flesh-formers and heat-producers.

Muscle follows different laws, both as regards its growth, which is limited in a far greater degree than fat, and its metamorphosis after use. Like every tissue, the nutrition of muscle depends upon some special part of food, the essential in this case being a nitrogenous material. True muscle can only be formed and reproduced from the flesh-formers of food; a hydro-carbon cannot make muscle, neither can any inorganic material, but only the material fitted for the purpose, to be found in vegetable food as gluten, or in animal food as the fleshy portion. Unlike fat, muscle cannot be stored up to an almost unlimited extent, dependent in great measure upon the nature of food, but its full vigour and vitality can only be maintained by use and exercise. The use of muscle necessitates its consumption, this calls for re-production. In health this demand is quickly answered, and there ensues as a result increased vitality, leading to improved nutrition and greater development. The blacksmith who is continually wielding his hammer gets great development of the muscles of the arm, the opera dancer from constant practice in dancing strengthens and increases the muscles of the leg. In these and like instances there is a combat between life and death; every muscular movement made in obedience to nervous influence generates force, dependent upon tissue consumption. If the destruction of tissue be kept within the bounds of reproduction, the stimulus thus given to vital energy has a beneficial effect; but if carried beyond this limit, the over-worked tissue from imperfect nutrition breaks down.

The changes that occur in the destruction or consumption of muscle appear in the urine. All the nitrogenous portion of muscle is by destruction converted into oxidised products, which are eliminated by this channel and by the skin. The sulphur also of muscle is at the same time oxidised. The products of this metamorphosis are urea, and its modifications, and sulphuric acid. The examination, therefore, of the liquid excreta affords evidence of the amount of muscular waste taking place, and can be used as the means of ascertaining whether this waste is kept within bounds.

At times the destruction of muscle exceeds the fair demands for use. In fevers and diseases where a high temperature is sustained, there is waste of muscle without equivalent reproduction. Assimilation is impaired, and the requisite amount of hydro-carbon or heat-factor being deficient, muscle is burnt up in place. In these diseases, the muscles rapidly waste, and examination of the urine shows the cause of waste. The urine contains excess of nitrogenous products, and also of sulphuric acid. In a recent case of acute pleurisy, with a pulse of 110 and temperature of 101, I obtained 2·8 grammes of sulphuric acid as passed in the urine in 24 hours. The skin was acting freely under the influence of antimony, so that an additional quantity of sulphuric acid must have been eliminated by this channel. This quantity is greatly in excess of that which would be passed under the same conditions of food and rest, in health.

Nervous tissue follows the same laws of nutrition as muscle. The separation of the chemical constituents of brain is a matter of difficulty, as the albuminoid and fatty matters are so incorporated as to render their separate determination a matter of great difficulty. The published analyses of brain matter show considerable variations, but agree in proving the organic portion to consist of nitrogenous and fatty matter. Obeying the ordinary laws of metamorphosis of these respective materials, the destruction of the fatty portion would not appear in the liquid excreta, but the nitrogenous portion would. The evidence thus given must be mingled with that afforded by muscular waste, and cannot separately be gauged; but from the excess of phosphoric acid brain tissue contains, the quantity of free phosphoric acid in the urine can to some extent be taken as the index of brain work. For correct results, considerations as to influence of food and surroundings must in all cases be taken into account.

Muscle, nerve, and the capillaries are the tissues immediately concerned in the production of all the active phenomena which constitute life. The use of these tissues necessitates their destruction, and the changes thus brought about—that is, the products of their metamorphosis—appear in large part in the liquid excreta; their constituents are in part resolved into carbonic acid and water, and are by the usual methods of analysis, lost sight of. Fat and other heat-regulators are converted solely into carbonic acid and water, and give no account of their previous existence in the liquid excreta. The hard tissues, such as bone, hair, and nails, take a different part in life to the soft tissues, and give no evidence of the same nutrient activity, dependent upon consumption and reproduction. The changes that occur in muscle or flesh have received due attention from physiologists and chemists, and the changes in nerve have also been in part recorded. Are not the evidences of capillary vitality as distinct and well marked as the vitality of either muscle or nerve? The capillaries take an active part in every vital phenomenon; the assimilation of food, its conversion into tissue, and its ultimate elimination all take place through their agency; except through their instrumentality, no act of nutrition can take place. They are the immediate agents in all the active processes of life, and are exposed to the wear and tear of active work, as well as to the influences of oxidation in all its full vigour. In the midst of all this increasing activity and change it is unreasonable to suppose that the capillaries take a mere passive part; that they are mere indestructible membrane, uninfluenced by the changes occurring around them, although mainly instrumental in bringing them about. Analysis of the tissues, the composition of food as fitted to fulfil the requirements of tissue formation, the secretions as evidence of the changes occurring in the tissues, as well as the changes wrought by disease, all show active vitality in the capillaries, and contradict the idea of their being mere passive instruments.

CHAPTER IX.

DISEASES OF NUTRITION.

Innutrition may be general or special, dependent either upon inadequate supply of food, or of some portion of food, as the albuminates, the hydro-carbons, or the inorganic portions; disease may also arise from non-assimilation even in the presence of an adequate supply of the different proximate aliments.

A healthy man injudiciously or inadequately fed, will in time originate disease, if the materials for the reconstruction of his tissues, exhausted by life, are not at hand; the rapidity with which disease is developed depending upon the deficiencies of diet, as well as upon influences of constitution.

The different essentials of a healthy diet have been shown, and the proportionate quantities of the principles of food have been indicated. Chemical examinations show that the albuminates of food present the same characters as the albuminates of tissue, that the inorganic matter of the different tissues is derived from similar substances existing in food, and that the animal temperature is kept up by the hydro-carbons or carbo-hydrates of food. Physiology and Pathology confirm the teachings of Chemistry.

The organic and inorganic portions of food have each separate influences in producing structural disease; under certain conditions these influences may be blended together, but at other times their action is distinct. Starvation is a disease dependent, as every one knows, upon deficiency of all the materials of food, both organic and inorganic; fatty degeneration upon deficiency of flesh-formers; and rickets upon deficiency of inorganic matter in bone. A further application of the laws of nutrition as influencing the production of other more subtle and obscure diseases, will show that innutrition of a special character is the main factor in these diseases. The question as to the extent to which diseases are attributable to insufficient supply, or to imperfect assimilation, is separate and distinct, but does not affect the chemical character of the alterations that take place in tissue construction. The diseases of nutrition, where the chemical composition of tissues undergoes alteration, are—starvation, arising from general innutrition; fatty degeneration, dependent on organic innutrition (deficiency of albuminates in flesh); and the diseases which on the theory here advocated depend upon inorganic innutrition. These last are scurvy, rickets, scrofula, consumption, cancer, and leprosy.

CHAPTER X.

STARVATION.

When the supply of food is cut off, the animal deprived of the material necessary for its support in a short time dies. All the phenomena of life cease, chemical changes occur uninfluenced by the mysterious force of vitality; the ordinary chemical changes in the tissues take place, which under the same conditions of temperature and atmospheric influence would occur in similar organic compounds devoid of organisation. Physiological action ceases, chemical action alone continues, eramacausis or decay sets in.

The first necessity of life is the maintenance of a proper and regular temperature. In man this is about 98° F., and under no conditions of food or climate can this temperature be materially varied for any length of time without the cessation of life. Under the influence of certain diseases, such as fever and inflammatory diseases, where there is quickened circulation and increased combustion, a rise of temperature takes place, but this is only in a limited degree, rarely exceeding 106° F.; even at this temperature, the waste going on from combustion would soon outrun the powers of assimilation and reproduction, and death from exhaustion would take place.

The variations of temperature under which human life in health can be supported, probably exceed by many degrees the variations under which any other animal can live. Different climates furnish their characteristics of the lower forms of animal life, but in all the vicissitudes of temperature which this globe furnishes, man can exist. The provisions of nature, as shown by the special conformation of man to maintain the normal temperature under extremes of either heat or cold, explain this.

The lungs and the skin are the chief agents by which the products of combustion are eliminated. When the external temperature is much below the temperature of the body, the chief work of elimination is thrown on the lungs; in cold weather if the body be at rest there is no perspiration, but when, on the other hand, the external temperature exceeds the animal temperature, copious perspiration takes place; by its evaporation the temperature of the skin and of the blood in its circulation through the capillaries is kept down. The activity and delicacy of the skin in man, and the readiness with which its activity, from superior nervous supply, can be called into action, fit him to bear higher temperatures than animals whose skin takes but little share in expiration or perspiration.

It was at one time believed that the human body could not bear a temperature much exceeding that of the tropics; this belief was in great measure owing to some experiments made by the celebrated Fahrenheit, related by Boerhave in his "Chemistry," and quoted by Sir Thomas Watson in his lectures delivered at King's College. Some animals were shut up in a sugar baker's stove where the mercury stood at 146° F. A sparrow died in seven minutes, a cat in a quarter of an hour, and a dog in twenty-eight minutes. Sir T. Watson, in his comments on the subject, remarks that probably the noxious air of the stove may have had to do with the speedy death of these animals. Was not death rather referable to deficient perspiration, and the consequent lack of adjustment of temperature? As a contrast to this inability of some of the lower animals to bear a high temperature, is the record of some experiments as given in the "Philosophical Transactions." Dr. Dobson, Dr. Fordyce, and Dr. Blagden are reported to have entered rooms heated to a high degree, at times naked, at other times clothed. In these experiments the extraordinarily high temperature of 260° F., was borne for a considerable time with but little inconvenience. Thermometers placed under the tongue or held in the hand showed only the normal animal temperature; the respiration was but little affected, while the pulse was very much quickened, being in one instance doubled. Watch chains or other pieces of metal carried about became so hot as scarcely to be touched; when they breathed on the thermometer, the mercury immediately sank several degrees, each act of expiration produced a pleasant feeling of coolness in the nostrils, and they cooled their fingers by breathing on them. In, and by the same heated air that they breathed, eggs were cooked hard, and beef steaks roasted in thirteen minutes by blowing air over them with bellows. The normal animal temperature was here sustained by the cooling effects of evaporation, arising from the conversion into steam or vapour of the copious perspiration with which the whole surface of the body was bedewed.

For the production of the compounds of respiration (carbonic acid and water) the hydro-carbons of food are necessary. Under ordinary circumstances we only notice their action in raising the animal temperature, because the surrounding atmosphere is of lower temperature; but where the converse happens, the cooling action of the products of combustion by evaporation, is called into play. The hydro-carbons of food act, therefore, as heat-regulators—at times their action is to increase, at other times to decrease animal temperature, as compared with the temperature of the surrounding atmosphere; whether their functions be that of increase or decrease, under all circumstances compatible with life, the maintenance of the animal temperature at a normal undeviating standard is mainly due to their action.

In this climate, under normal conditions of health, where the balance between supply and demand is properly adjusted, the hydro-carbons of food furnish fuel for combustion to preserve the natural animal temperature. As long as there is the supply of material in proper proportions from this source, there is but little call upon the tissues, but directly the supply of food is cut off, tissue waste occurs. The first call is upon the repository of heat-producers, the fat; this tissue is consumed, and after that such tissues as by combustion can furnish the essentials of respiration (carbonic acid and water) are by degrees destroyed. Muscle and flesh being the tissues next to fat most easily converted into the necessary heat-giving compounds, suffer in turn. In starvation, first of all the fat in the body disappears, then the muscle and fleshy organs waste, and as these become so diminished as no longer to yield up to combustion the necessary quantity of matter to keep up normal heat, the fire of life dies out for want of fuel.

The tissues, which are not readily liable to oxydising influences, take but little part in maintaining the normal temperature, and consequently show but little if any impairment of structure after death from starvation. The bones and skin of a starved animal, if compared with the same structures of an animal killed in health, show no perceptible loss of weight; but the fat and flesh lose weight very perceptibly.

Many of the phenomena of life can only take place by means of organised tissue, each tissue or organ being endowed with special functions, influenced by certain conditions, amongst which construction and nerve influence bear important parts. There is reason for believing that the temperature can be maintained or regulated independently of organisation; that chemical action productive of heat can take place on certain proximate principles in the blood, without the conversion of these alimentary principles into organised tissue.

The hare is without fat, so that in this case heat must be kept up either by assimilation of carbo-hydrates from the food, and their direct combustion from the blood by oxidation in the capillaries, or heat must be obtained at the expense of muscle or other oxydisable tissue. As a properly fed hare, in its natural state, neither gains nor loses weight, evidence is against the supposition of the muscles being called upon to supply fuel for combustion. In health muscle is liable to only slow changes, and these changes are wrought by agencies which produce increased development from increased activity, rather than by influences of food. If it be granted that the regulation of the normal animal temperature depends upon chemical action, and that this action takes place in the capillaries of certain organs (and upon this point there can be but little doubt), the presence of the material to produce the necessary chemical changes is all that is necessary. Whether the hydro-carbons in the blood as it circulates through the capillaries are the product of direct assimilation, or of tissue metamorphosis, can be of little moment. To assume that there exists a necessity for organisation of carbro-hydrates before their combustion, is to assume that the capillaries can distinguish between a chemical compound in the blood, the product of assimilation, and a precisely similar compound derived from organised tissue.

Human beings vary greatly as to their power of fat assimilation; some show no inclination to accumulate fat under any changes of diet, while in others the difficulty is to avoid an undue accumulation of fat. The temperature of both fat and lean is, however, the same; as the lean person has no fat, the organisation of fat can have nothing to do with his temperature. In the case where organisation is a necessity of function, the evidence is clear that function is dependent upon organisation. The man of intellect possesses a well-developed brain; the strong man possesses good muscle.

A starving animal lives as long as he can furnish fuel to regulate the vital fire; he dies directly the stock is insufficient for this purpose. Cold aids starvation in a very great degree. Animals can be kept for weeks together without food, where the external temperature does not tax the heat-regulating functions of the lungs and skin, but exposure to cold for a few hours without food soon produces starvation. Currie mentions a case where an individual unable to swallow lost 100 pounds in weight in a month; Martell (Trans. Lin. Coll., vol. xi, page 411) shows that a fat pig overwhelmed in a slip of earth lived 100 days without food, and was found to have diminished more than ·120lbs. In these cases the surrounding temperature must have been such as to make no great call upon the heat-regulating functions. Hybernating animals, who coil themselves up in a warm corner, with a large accumulation of heat-producing tissue in the shape of fat, sustain life without food, except that afforded by tissue waste, during the winter; if radiation from their bodies took place to any great extent, or if they were unprotected from the effect of cold, the necessary increase in combustion of fuel would soon bring on death. No winter campaign is without numerous instances of soldiers quickly starved to death in cold weather after a short abstinence from food.

That starvation affects but slightly the inorganic portions of certain structures, such as bone and skin, has been long recognised. The action on the capillaries is as real and as readily open to demonstration as in the case of bone and skin, as the following investigation shows:—

Two full grown young rabbits were selected for examination; they were of the same age, color, and belonged to the same brood, one being rather better developed than the other; there was a difference of about half-a-pound in their weight.

No. 1, the smaller of the two, was killed immediately and the organs examined.

The lungs, liver, spleen, heart, and kidneys weighed in the fresh state together 75·43 grammes.

These yielded together :—

	grammes.
Bases	·442
Phosphoric Acid	·294

Or per cent. of organs examined :—

	grammes.
Bases	·586
Phosphoric Acid	·390

No. 2 died after a week's starvation. Death took place on the eighth day, after a cold frosty night. The weather preceding this night had been mild. The animal appeared healthy and well, with plenty of activity, the previous day. As in the other case, the organs were examined immediately after death.

The lungs, liver, spleen, heart, and kidneys (the same organs as were examined in No. 1) weighed in the fresh state 47·94 grammes.

These yielded together :—

	grammes.
Bases	·500
Phosphoric Acid	·202

Or per cent. of organs examined :—

	grammes.
Bases	1·042
Phosphoric Acid	·421

The diminution of weight is very marked, for in the case of the animal killed in health all the organs weighed 75·43 grammes, while the same organs in the starved animal only weighed 47·94 grammes, thus showing a loss of about 30 per cent. This loss was confined to the organic and aqueous portions of the tissues; there was no loss in the inorganic portions, for the total inorganic matter was slightly larger in the starved than in the healthy animal, and if shown in the proportion per cent. according to the method adopted in my former examinations, would appear still larger. The organic portions of the organs are shown to have been greatly diminished in the case of starvation, while the inorganic portions had not undergone any such diminution.

Quantitative analysis shows, in cases of starvation, a per centage increase of inorganic matter, due to absorption of organic matter and reduction of weight, while in cases of death from certain organic wasting diseases, as phthisis and scrofula, I have found decrease in the proportionate quantities of inorganic material. I am inclined to the opinion that a further investigation of the subject, carried out in the direction pointed out, will show the same decrease of inorganic matter in the vascular tissues in cancer and leprosy.

Starvation affords evidence of organic innutrition from absorption of organic matter for heat production; in scrofula and allied diseases the innutrition is in the inorganic matter, either from non-absorption of the proper material from the food, or from non-assimilation in the tissues.

CHAPTER XI.

FATTY DEGENERATION.

The changes that take place in this disease depend upon influences of organic nutrition. The tissues or organs which are liable to this change are the nitrogenous or fleshy tissues, which by alterations in structure have their fleshy or nitrogenous material replaced by fat. All tissues which contain nitrogenous matter, either as albuminates or as gelatine-yielding compounds, are liable to undergo fatty degeneration. Nature works by thrifty, crafty means, striving to do right, and when thwarted in her regular endeavour, struggles, sometimes in vain, to set wrong, right. In healthy nutrition—that is, where there is healthy assimilation—if any portion of the heat-giving and life-sustaining elements of food be wanting, the effort that nature makes to repair the deficiency can be clearly followed. In starvation it has been shown that certain tissues are, in cases of necessity, burnt up in place of food; the nitrogenous portion of tissue is made to do work, which under properly regulated circumstances, would be done by the alimentary principle of food, which falls within the character of a hydro-carbon. If for the healthy fabrication of tissue, any one alimentary principle be wanting, its place is supplied by some other material; as a man, inhabiting a house of brick or stone, would repair the dilapidations of time and weather by any such material as was at hand, if he were unable to obtain the material like the original, of which his house was built. In the absence of the proper albuminates of food, fats are made use of; the proper nitrogenous element of flesh is replaced by a hydro-carbon—that is, fatty degeneration ensues.

By this term is meant a distinct condition, from mere excessive deposit of fat. This latter may take place under perfect conditions of nutrition, from excessive assimilation, and is much more under control than the other.

In excessive fat deposit, the fat-formers of food are assimilated in greater quantity than the immediate wants of the system require. A larger stock of fuel is provided than is necessary to keep up the normal temperature; this is stored up for future use. The cellular tissue becomes the coal cellar of the body, and is stocked with fuel. Up to a certain point this process of laying by fuel is unattended by ill consequences; but if it goes too far, the stored up fat produces uncomfortable and distressing symptoms. The abdominal cavity becomes loaded with fat, as also the thoracic cavity, impeding from mere pressure the functions of the different organs contained in each; the heart becomes surrounded with fat, so that extra exertion produces palpitation; and the extra weight of the body, as well as the impediment, offered by the presence of fat in excess, to the free action of the muscles, tend to make locomotion inconvenient.

As the chemical composition of the tissues in these two conditions is different, so also the pathology and treatment vary. In mere fatty increase, exercise so as to consume by degrees the stock of fuel laid up, combined with a dietary which excludes fat-formers, will in time produce a very marked effect in allaying discomfort. In fatty degeneration the cause of disease is not so readily removed, nor is the treatment in all cases successful. At times where the disease can be traced to errors of habit or diet, treatment directed towards the removal of these predisposing or exciting causes may do much to restore the lost or disturbed balance of tissue nutrition; in other cases assimilation may have become so reduced in power, and tone, by alteration of tissue, that the healthy restoration of tissue cannot be affected.

Arteries, like other nitrogenous tissues, are liable to fatty degeneration, atheroma. In this disease the arterial coats undergo fatty disintegration. There is another arterial disease, the converse of this—I allude to calcification of arteries. In this disease there is a deposit of tricalcic phosphate in the inner membrane of arteries, principally occurring just beneath the epithelial membrane, but at times invading the whole calibre of the artery. I have often observed plates of bony matter in the large arteries of animals, slaughtered for food. Under the microscope these plates do not show the minute conformation or structure of bone, but chemical analysis shows that they are composed of bone phosphate; so that although the organisation of bone is wanting, the chemical materials of bone are present. The deposit takes place in that portion of the artery in which, under normal conditions of tissue structure, tissue phosphate exists in largest proportion—the inner coat. By an alteration or perversion of nutrition, bone phosphate is deposited in the place of tissue phosphate. This change in chemical composition may take place to a very large extent. In a case of sudden death, where the cause of death was obscure, I had to make a post-mortem examination. The whole arterial system was in a state of rigidity from calcification. The femoral was rigid enough to be held out horizontally without bending. Death took place from rupture of the coronary artery round the heart, and extravasation of blood into the pericardium.

In atheroma and ossification of arteries we have illustrations of alterations in normal tissue structure: in the first, fatty matter replaces the normal nitrogenous matter, with or without deficiency of inorganic matter; in the second case, bone phosphate replaces tissue phosphate. In atheroma the change is in the constitution of the organic matter, in ossification it is the mineral matter that undergoes alteration.

CHAPTER XII.

SCURVY.

The conditions characteristic of this disease are always accompanied with a deficiency in the food of the materials for the formation of tissue phosphate; or if these materials be present in sufficient quantity, examination of the food in use shows that the salts, which enter into the formation of tissue phosphate, are in an insoluble, or only partially soluble state. Different explanations have been given by various writers as to the causes of scurvy; the two theories most prominently brought before the profession are that propounded some time ago by Dr. Garrod, and that more recently by Dr. Ralfe. Both treat the blood as a substance which must of necessity have a certain fixed normal chemical constitution, and consider the disease to be caused by some deficiency in its healthy composition. Neither theory points out the function of the deficient material in tissue formation. Accurate information from analyses of blood is difficult to obtain, both on account of the difficulty of obtaining healthy blood, and blood in disease, for comparative examination, and the difficulties that beset the elimination of possible sources of error, in such a complex and variable fluid, as the blood. If we consider that the blood contains all the materials for the nutrition and fabrication of tissue, both organic and inorganic, as well as the products for combustion for keeping up temperature, and the products of metamorphosis of tissue prior to elimination, it is obvious that a quantitative analysis of a portion must be liable to various fluctuating agencies. Venous and arterial blood differ materially in composition; the different organs of the body exercise their specific functions on the blood, each altering its composition in some way, so that local blood-letting must give always a doubtful indication of the condition of the whole blood. On the other hand, the tissues have, in health, each a fixed and definite composition, which is not altered by the same causes which would alter the blood. If a man drink largely of water this must pass through his blood before elimination, and while in transitû must dilute the blood to a perceptible degree. Other ingredients necessary for nourishment may also exist in excess of nutrient requirements, for by over-eating the blood may be over-loaded with the products of food absorption. The composition of the blood must depend upon powers of digestion and nature of food (the ingesta); upon the calls made by life upon the ingesta; and upon the activity of the different eliminating organs to remove useless and effete matter (the egesta). There is no organisation in blood, and no nerve influence or vitality which can regulate the balance of supply and demand as in the organised vital tissues. All the essentials of tissue formation exist there, but in no fixed relative proportion, and quantitative analysis cannot therefore lead to instructive conclusions, as no data can be obtained on which to found an accurate estimate of its average composition.

The influence of the blood in the production of diseases of nutrition must depend upon one of two causes—either some chemical alteration in the blood, interfering with its functions, or the deficiency of some one or more materials necessary for the different purposes of life. One of the chief purposes of food, and of its alimentary principles as found in the blood, is tissue formation. Of the different inorganic materials required for tissue renewal and fabrication, analysis shows that tissue phosphate takes an important part in capillary formation, and a consideration of the conditions which produce scurvy, the symptoms of the disease, and the treatment, illustrate in a very marked way the theory of capillary construction which I advocate.

On reference to the analytical evidence in the Appendix, page XIX., it will be seen that an adult on the diet there given, consumes daily about 3½ grammes of phosphoric acid, together with the quantity of bases, by transposition, necessary to form tissue phosphate. An adult passes on the average about 2½ grammes of phosphoric acid in his urine, about three-fourths of which can by synthesis, according to my experiments, be shown to enter into the composition of tissue phosphate, the remainder of the phosphoric acid representing brain and nerve use. Two grammes and a half out of three grammes and a half are thus accounted for. The *fæces* contain a portion of insoluble phosphates which must be deducted from the quantity available in food for nutrient purposes, as this portion represents insoluble phosphates which have never been assimilated. This amounts to one-third of a gramme. Further, all the analyses given refer to uncooked food, and as boiling food—especially meat or potatoes—dissolves out a portion of phosphates, still further reduction must be made in estimating the quantity of phosphoric acid, which, on this diet, would take part in nutrition. (If the water that potatoes or meat have been boiled in, be examined, very perceptible quantities of phosphoric acid will be found). With the necessary deductions for insoluble phosphates and loss in cooking, this diet would only show a very slight excess of phosphates, over and above that required to repair daily waste in the tissues. It may therefore be held, that a fair ordinary diet contains only a sufficiency of inorganic matter, to furnish the necessary daily supply to repair waste. Any circumstances which either lessen the quantities of phosphates, or render them insoluble, and thus prevent their absorption, will consequently produce symptoms dependent on imperfect supply.

Dr. Parkes, in his "Practical Hygiene" (p. 462, fourth edition), says:—"The peculiar state of malnutrition we "call scurvy is now known not to be the consequence "of general starvation, though it is doubtless greatly aided "by this. Men have been fed with an amount of nitro-"genous and fatty food, sufficient not only to keep them "in condition, but to cause them to gain weight, and yet "have got scurvy. The starches have also been given in "quite sufficient amount without preventing it. It seems, "indeed, clear that it is to the absence of some of "the constituents of the fourth dietetic group, the salts, "that we must look for the cause."

The conditions which favour an outburst of scurvy are, want of wholesome, fresh meat, of fruit, and succulent vegetables, accompanied generally with the use of salt meat. The greater part of the phosphates in an ordinary diet are derived from fresh meat, potatoes, and flour—this last principally being used as bread, and in the case of seamen as biscuit. Fresh meat and potatoes both contain their phosphates in a more soluble form than flour. If either fresh meat or potatoes be boiled, and the water in which either has been boiled, be examined for phosphoric acid, perceptible quantities of this acid will be found. With flour this is not the case. As the scorbutic diet contains no potatoes, or other fresh vegetables, the phosphatic supply must depend upon the remaining articles of diet, which contain phosphates, and these are, in ordinary cases, salt meat and hard biscuit. Both these are poor phosphate bearers, inasmuch as salt meat is very deficient in phosphates compared with fresh meat, and biscuit carries its phosphates in an insoluble form.

The effect of salting meat is to deprive it of a large quantity of its phosphates, as well as a portion of its albuminates; the phosphates abstracted are of necessity the most soluble, and therefore most readily assimilated; consequently, the best tissue phosphate formers. Two samples of fresh beef show respectively ·256 and ·320 per cent. of phosphoric acid; a sample of salt beef obtained from the stores of H.M.S. *Hector*, while in commission, showed only ·147 per cent. of phosphoric acid. A specimen of brine used by a butcher for preserving spare scraps of meat, showed ·707 grammes of phosphoric acid in 100 c. c., and gave a considerable precipitate of albumen on the application of heat and nitric acid. In the examination of the salt meat, the result of which is given, the meat was examined without soaking. Before use in the navy, it is soaked for some time in water to remove the brine; the effect of this would be, without doubt, to remove a still further quantity of phosphates, so that by the time it is ready for consumption, it can contain but little phosphoric acid or phosphates. In estimating the relative quantities of phosphoric acid in fresh and salt meat, the fact must be borne in mind that salting meat reduces its bulk; for the abstraction of the juices, which takes place in salting, consolidates the fibre, and reduces the weight, so that a pound of fresh meat would not yield nearly that quantity of salt meat. If the correction for loss of weight be made, the loss of phosphates becomes still more marked.

Pemmican has attracted some attention from its use in the late Arctic Expedition. Judging from the analysis by Dr. Frankland, as given in the *Lancet*, of June 23rd, 1877, this meat ought to be of great use in preventing scurvy, if the phosphates it contains be soluble, or be rendered so by the use of citric acid. The analysis shows, in 100 parts—water 6·75, albuminates 35·09, fats 56·42, and ash or mineral matter 1·74. This last contained phosphates of lime and magnesia ·06, alkaline phosphates 1·349, and common salt ·107. This shows five or six times the quantity of phosphatic salts that salt meat contains. From these comparisons it appears that dried meat would be a better and more nutritious food than salt meat.

Wheat flour contains phosphates in considerable quantities; so that if life were sustained on bread and water, and bread were taken in sufficient quantity to supply the necessary amount of albuminates and heat-producers, there would be a sufficiency of mineral matter for phosphatic supply. But the solubility of the phosphates in flour is not so great as in meat and vegetables, and on this food alone it would be necessary to aid the assimilation of mineral matter by the action of some solvent. The fresh flesh of herbivora contains slight excess of phosphoric acid, as well as small quantities of sulphuric acid—both aids to the solvency of phosphates; the anti-scorbutic action of fresh meat depends upon this ready solubility of phosphates. The potato, fresh vegetables, and fruit, act well because their phosphates are also soluble from the presence of malic, citric, or other acids, which act as solvents. Flour contains neither malic, citric, or other free acid, neither does it contain any free phosphoric acid.

What is the composition of lime juice, and why should it act as an anti-scorbutic? If my theory of capillary formation and nutrition be accepted, the explanation of its action is ready and simple. The most active principle in lime juice is citric acid, and to the presence of this acid, lime juice mainly owes its efficacy as an anti-scorbutic. This has been shown by experiments which demonstrate that it is the sole component material of lime juice, which in a separate state and alone has anti-scorbutic properties. Citric acid alone acts nearly as well as an anti-scorbutic as lime juice, the small quantity of potash entering into the composition of lime juice, adding slightly to its efficacy. The proportion of citric acid in lemon juice, is from 5 to 7 per cent. of the fresh juice. Potash exists in the proportion of about ·22 per cent., and phosphoric acid about ·03 per cent. The ordinary allowance in the navy is about 1oz. per day. This would show about 2 grammes of citric acid, ·07 grammes of potash, and ·01 of phosphoric acid in the sailor's daily quantity of lemon juice. The last two, the potash and phosphoric acid, can have but little effect as anti-scorbutics, as they exist in such infinitesimal quantities, and the other articles of diet contain both in far larger quantities; the allowance of biscuit would contain ten times the quantity or more of potash, and phosphoric acid in sufficient quantities for dietary purposes, if it were in solution, or were capable of being rendered so by a proper solvent. The anti-scorbutic action of lemon juice is thus reduced to its citric acid, and the efficacy of this depends upon the conversion of insoluble phosphates into soluble for the formation of tissue phosphate.

The action of citric acid is remarkable. It is a complete and perfect solvent of phosphates; even tricalcic phosphate (bone phosphate) is in certain proportions completely dissolved by it. I have tried all the mineral acids, as well as many organic acids—tartaric, acetic, and oxalic amongst the number—and find that as a solvent of phosphates no acid equals citric acid. The mineral acids are not true solvents; by their stronger affinity for the bases of phosphates, they simply cause decomposition, producing sulphates, chlorides, or nitrates, according to the nature of the acid used, and setting free phosphoric acid, which remains in solution. The organic acids act as solvents without producing any such decomposition. As a free acid in the absence of the proper bases, phosphoric acid plays but a minor part in nutrition; even in the presence of bases combined with mineral acids the action of phosphoric acid as a true phosphate-former is questionable, but if the bases be combined with a feeble acid such as carbonic, tissue phosphate can be produced in the presence of phosphoric acid and the requisite bases. These are points of chemistry which can be easily verified by experiment. The reactions that take place in the presence of sulphuric acid and tricalcic phosphate can be readily followed and will help to show that analagous reactions take place between other mineral acids and insoluble phosphates. If sulphuric acid be added with water to bone phosphate, in the proportion of two parts by weight of acid to three parts by weight of bone phosphate, the result is the formation of two parts of sulphate of lime and one of phosphate of lime (monocalcic phosphate)—$3\ Ca.\ O.\ PO_5 + Aq. + 2\ SO_3 = 2\ (Ca.\ O, SO_3) + Ca.\ O, PO_5 + Aq.$ If equal parts of bone phosphate and sulphuric acid be used, the whole of the lime is with proper precautions completely removed as the following equation shows:—$3\ Ca.\ O, PO_5 + 3\ SO_3 + Aq. = 3\ (Ca.\ O, SO_3) + PO_5 + Aq.$ In this latter case the phosphoric acid remains in solution, and unless searched for properly, its presence may be overlooked. In this case the fresh combination between the sulphuric acid and the base is evident, because the resulting compound, sulphate of lime, is insoluble. If instead of bone phosphate, magnesian phosphate be used, an analogous decompositon takes place; but as sulphate of magnesia is soluble, as also phosphoric acid, the result is not so apparent. Corresponding reactions take place with the other mineral acids, so that these acids are not true solvents of phosphates, but act apparently as solvents, by forming soluble compounds with the bases of the phosphates, leaving the previously combined phosphoric acid, free. Citric acid acts differently. If a tissue phosphate of known composition be dissolved in a mineral acid, and then rendered alkaline by ammonia, the precipitate thus formed will not be found to be identical with the tissue phosphate dissolved—some portion of the bases remain combined with the mineral acid used; but if citric acid be used as the solvent, the whole of the tissue phosphate can be recovered in its original proportions and quantities. Citric acid also prevents the formation of insoluble phosphates of iron, magnesia and alumina, except as components of tissue phosphate in an alkaline solution, and the consequent loss of phosphoric acid required for the formation of tissue phosphate. It economises phosphoric acid and bases, for the fabrication of tissue phosphate for purposes of nutrition, by preventing the loss of phosphoric acid, which might otherwise form insoluble phosphates, useless in nutrition. In all my experiments for estimating phosphoric acid, I have made use of citric acid to prevent the formation of uncertain precipitates of phosphoric acid and bases, with the best results. The only precipitates that I have found to occur in its presence, even in a strongly ammoniacal solution, are the ammonio-magnesian phosphate, tissue phosphate, and bone phosphate. The discrimination between these is easy when their composition is recognised. Neither alumina, iron, or magnesia is precipitated as a simple phosphate, even in an ammoniacal solution, if citric acid be present in sufficient quantities. Without the use of citric acid, tissue phosphate may be calculated as ammonio-magnesian phosphate, and that this has been done I feel confident, from a comparison of my investigations with the published results of other investigators. These facts, therefore, as regards the action of citric acid, together with the doctrine of capillary nutrition, tend to show that the efficacy of lime juice as an anti-scorbutic depends mainly on the presence of citric acid, and is referable to the solvent powers of this acid on phosphates.

This theory, which shows scurvy to be induced by a deficiency of the materials for the formation of tissue phosphate, or of their existence in an insoluble, and therefore not easily assimilated form, is not in any way opposed to the facts which have been noted by others respecting the disease.

I acknowledge all the phenomena of the disease as recorded, but put a different explanation on the cause, and trace the condition brought about in scurvy to the insufficient nourishment of the capillaries, wrought by the deficiency of their inorganic materials. I admit the deficiency of potash, as taught by Dr. Garrod, but maintain that this deficiency only acts, as far as the potash found to be deficient, can be turned to account in the formation of tissue phosphate. If all the other ingredients—lime, magnesia, soda, and phosphoric acid—were present in sufficient quantities, potash would then be of material service. But as potash is the base, which of all others exists in larger quantities in the inorganic portions of food, this special deficiency is not likely to happen. If the potash is deficient, it may be taken as granted that the other ingredients for the formation of tissue phosphate are also wanting, and in their absence in an easily assimilated form, potash alone is useless as an anti-scorbutic.

Dr. Ralfe has lately published in the *Lancet* some interesting facts connected with scurvy. His analysis of the dietary of a seaman, deprived of fresh vegetables and fresh meat, and confined to the use of salt meat and biscuit, shows a marked diminution as regards the ingestion of phosphates;

his analyses of the urine of a scorbutic patient show a great decrease of phosphates in the egesta, and an increase of phosphates as convalescence occurs. This accords with my views, but the deductions that he draws offer no explanation of the anti-scorbutic action of lime juice. According to Dr. Ralfe's views, the chief factor in inducing scurvy is a diminution of the alkalinity of the blood. If this be the cause of scurvy, how can the ingestion of large quantities of citric acid restore lost alkalinity? The converse would be the case, deficient alkalinity would be heightened by increased acidity. The deficiency of alkaline carbonates is a part of the deficiency of inorganic materials necessary for the formation of tissue phosphate, and cannot alone act as inducing scurvy. If the sole deficiency were in alkaline carbonates, their ingestion would cure the disease, but we know that this is not the case.

The similarity of the symptoms observed in animals whose blood has been rendered neutral or acid by artificial means, to those which occur in scurvy, admits of explanation in accordance with my views of capillary nutrition. Under usual conditions of health tissue phosphate is formed from monophosphates, and carbonates and chlorides. If the blood be in its normal alkaline conditions, the chemical reactions that produce tissue phosphate can take place, and assimilation under the influence of nutrition: but if the blood by the agency of acids, more particularly the mineral acids, be rendered abnormally acid, tissue phosphate is not formed. The bases which should go to the formation of this salt are combined with the stronger mineral acids, as chlorides or sulphates, &c., and cannot be assimilated in this soluble condition. In the laboratory tissue phosphate is not thrown down from any strongly acid solution, neither can it be in the blood, if this be rendered acid. The same results occur as if there were an absence of material for tissue phosphate formation. The symptoms of innutrition are identical, under conditions which arise either from absence of proper material for tissue formation, or from non-assimilation, independently of the cause of this last.

Oxalic acid and its soluble salts have been proposed as anti-scorbutics, and recently their use in this way has been re-introduced to the notice of the profession. Oxalic acid, like tartaric, acetic, and citric acid, is a solvent of phosphates, and therefore to some extent anti-scorbutic. Citric acid far surpasses all others in its efficacy, and it is difficult to see on what grounds oxalic acid or its salts should be preferred to citric acid. The poisonous nature of oxalic acid must serve as a fatal barrier to its use in any but skilled hands, and even then its use is open to very grave objections, especially as better results can be obtained by more efficacious and less objectionable means.

CHAPTER XIII.

MINERAL THEORY OF WASTING DISEASES.

The different diseases of nutrition may depend either upon deficiency of the proper alimentary principles of food, in whole or in part, or upon imperfect assimilation.

The healthy performance of the functions of the different organs or tissues, which take part in assimilation, depends in great measure, upon the proper restoration of their constructive materials; the portions used up in life, whether of organic or inorganic origin, must be replaced by similar compounds, the material for which is furnished by the food, and organised in the system. If it can be shown that any tissue is in its healthy state, composed of certain proportions of organic and inorganic matter, it is only reasonable to assume that any causes which alter these relative proportions produce a condition incompatible with health. Bone, which consists of organic and inorganic matter, is liable to a disease, rickets, which clearly shows, on chemical examination, a deficiency of the inorganic matter. This condition only occurs in childhood, because at this period of life there is a gradual development of bone, which as puberty is reached, ceases. Bone then stops growing, and shows but slight evidence of subsequent structural change. As long as there is any growth in bone there is a risk of imperfect nourishment from deficient inorganic matter; either the food is wanting in phosphate of lime, or there is a defect in its assimilation; and of these two possible causes of the disease, deficiency in proper food supply is the more frequent. In rickets, bone becomes soft and pliable, yielding to any weight or strain put upon it, so that the lower limbs become bowed, the spine curved, and the cranium enlarged; the skeleton, from its imperfect construction, fails to fulfil the duties which properly belong to it.

In rickets the inorganic deficiency is recognised, as productive of the disease, because the deficiency is obvious. The inorganic material bears a large proportion to the organic, and as the construction of bone is known, any great alteration in the relative proportion of organic and inorganic matter, is readily apparent; but in structures which show a small proportion of inorganic matter, deficiency of this may readily be overlooked, especially when, as in capillaries, the existence of inorganic matter has not even been recognised. As an additional cause likely to obscure structural changes in the capillaries, the fact must be borne in mind that the chemical examination of capillaries can only be made together with large quantities of surrounding tissue; capillaries cannot be isolated and separated for analysis.

It may be matter of surprise to some that the microscope fails to show the presence of inorganic matter, as tissue phosphate, in the capillaries, or in the arteries, but microscopical examination of bone shows an analogous condition; bone phosphate and tissue phosphate present points of similarity; they both form amorphous, nearly insoluble compounds, which in the case of both bone and capillary construction are blended with organic matter, so as to form a structure in which the inorganic matter is not apparent to the sight. Under the microscope, all the minute anatomy of bone and its organisation is shown, but there is no division of organic and inorganic components; if the microscope alone were depended upon, the inorganic constituents of bone could not be demonstrated. The same reasoning holds good with respect to capillaries. There are certain alterations of structure between healthy and diseased bone, which can be shown by microscopical examination, but these depend upon structural alteration as applied to minute anatomy, and not to differences of chemical composition; for the demonstration of the last, quantitative analysis is necessary.

In the premises it has been shown, that in health the inorganic materials for the formation of tissue phosphate exist in the arteries, and in all vascular tissue, and that in death from starvation the inorganic matter in vascular tissue is not in reality diminished, but is apparently increased.

In starvation, if due allowance be made for the loss of organic matter caused by consumption of carbonacious matter, the inorganic matter is found in about the same quantities as in health; but the quantitative examination of oxydisable tissue, if this be rendered per cent, shows a larger proportion of inorganic matter to organic than in health. Analyses conducted for the determination of the inorganic matter in cases of death from disease, which may be classed under any of the varieties of struma, phthisis, &c., show the converse of this. This deficiency of inorganic matter is not confined to the organs or tissues which are apparently the seat of the disease, but in a greater or lesser degree pervades the whole capillary system. A healthy rabbit gave ·976 grammes of inorganic matter in 100 grammes of fresh tissue; a starved rabbit showed 1·463 grammes of inorganic matter in 100 grammes of fresh tissue; an apparent increase of nearly ·5 per cent. in the proportion of inorganic to organic matter. Of this quantity of inorganic matter, phosphoric acid formed in the tissues of the healthy rabbit ·390 grammes per cent.; in the starved rabbit ·421 per cent. Analysis of the spleen, liver, kidney (one), and lungs of an adult, who died of strumous abscess of one kidney (not that which was analysed), showed an average of ·175 grammes of phosphoric acid in each 100 grammes of tissues examined; this is a much smaller proportion of phosphoric acid than I have found in any organ of an animal killed in health. The nearest approach to it was in the kidney of a pig which showed ·244 per cent. of phosphoric acid; between ·175 and ·244 there is a marked difference, especially when the ·175 shows the average of four organs examined, and the ·244 represents the lowest quantity found in some thirty or forty analyses of healthy organs. In this case of kidney disease, death took place slowly, and was preceded for several days by inability to take any food, so that there was extreme emaciation; the organic portions of the tissues examined had, as in starvation, been in part consumed, showing reduction of weight; yet the evidence is clear of a large reduction in the proportionate quantity of inorganic matter. There was deficiency both of organic and inorganic material, the loss of the latter being in excess of the loss of the former. In considering the theory of starvation, the loss of organic matter has been accounted for—it is used up as fuel for maintaining temperature; the deficiency of inorganic matter has a separate and independent cause, the consequence of defective capillary nutrition.

In all cases of death from consumption or analagous diseases that I have yet had chances of examining, this deficiency has been well-marked, and leads me to look upon it as an invariable characteristic of the wasting organic diseases, and if the symptoms, points of analogy, and general pathology of these diseases be considered, it will be seen that one common cause is more apparent than a superficial observation would suggest, and that the theory of capillary inefficiency can be made to explain many of the phenomena of these diseases.

In the different revolutions of medical opinion as to the origin of diseases, various theories have been propounded, each influencing more or less the general treatment of disease. Not many years ago, almost every ailment was looked upon as dependent upon the presence of some active and substantial agent productive of the disease, there was an entity or supposed entity about disease, which required to be treated by active measures. The human body was looked upon as a fertile and inviting country, liable to invasions from all kinds of enemies, and the duty of the practitioner consisted in trying to expel the supposed enemy *vi et armis*. The sovereign remedy for all ills was then, bleeding, purgation, and the antiphlogistic treatment. As the failure of this plan began to dawn upon the minds of the public, a revulsion of treatment on the part of the profession took place, and the repleting and alcoholic treatment had its day. Beef tea, alcohol, &c., were prescribed, with but little discrimination, *ad libitum*. Very recently, professional opinion is looking to nervous and lymphatic influence for the explanation of the symptoms of diseases which are at all obscure or remote in their origin. Will this last view stand any better test than the others, or does it offer any more rational theory for the treatment of disease than the former theories did?

That nervous influence greatly affects disease no one can be prepared to deny, but whether it can be in health the origin and first cause of disease is a matter open to argument. The proper function of healthy brain and nervous matter is to convey natural impressions in accordance with healthy nutrition; but these may be altered by causes which have a centric or eccentric origin. Caries in a tooth will produce intense pain from eccentric irritation, while any lesion of a nerve centre will produce symptoms dependent upon centric causes.

Healthy nerve action, in its influence on different functions and vital changes, may be likened to the galvanic or electric action set up in the process of electrotyping. The requirements for this process are, chemical action to produce the electric current, wires or other conductors to convey the electricity, and solutions to yield on decomposition different metals. As long as the whole arrangement is complete, chemical changes take place in the solution acted on by the electric current, but directly there is any cessation in the production of electricity, or in its transmission, there is no further action in the solution. Under the influence of electricity certain chemical changes take place, which cease the moment that the current is checked; in these changes there is nothing at variance with the laws of chemistry, but without the aid of the electric current these changes do not take place. In like manner, under nerve influence, changes in tissue take place, necessary for reproduction and metamorphosis, but if these changes be followed it will be found that they are not antagonistic to the known laws of chemistry. Nerve influence is necessary for the production of the chemical changes which constitute life, as in electrotyping the electric current is necessary for the resultant chemical changes.

If the chemist, in the process of electrotyping, find that his solution, which ought to show a certain composition, has undergone material alteration, he knows that until he can rectify these deficiences the results will be altered—perfect deposition of the metal does not take place. The error may rest not with the exciting or regulating agent, electricity, but with the medium which has to be acted on. Without the proper chemical compounds he cannot get at desired results. In diseases which are referable to defective tissue nutrition, and where the error can be traced to deficiences in the food, or in some of its alimentary principles, why should we be driven to refer the cause to some mystic nerve influence? If a rickety child, reared on food wanting in phosphates of lime, gets deformity from bone-softening, is there any occasion to talk of nerve influence? The condition is to be explained on purely chemical grounds; the deficiency in the food, of the proper materials for strengthening bone. In other diseases, also, the cause can be as clearly traced to food deficiency, without assuming that nerve influence has any responsibility. What has nerve influence to do with the primary cause of scurvy or starvation? Nervous tissue, like every other tissue, has its normal chemical composition, and every, or any, deviation from this, dependent on impaired or imperfect nutrition, leads doubtless to unhealthy action; as knowledge of the chemical composition and of the nutrition of nerve increases, in all probability, many of the diseases which are now attributable to nervous influence, will be shown to have their origin in innutrition.

Recently attention has been directed to the condition of the absorbents in tubercular, cancerous, and allied diseases, and the origin of these diseases has been attributed in great measure to their influence. That the chyliferous vessels and lymphatics present an altered appearance during the progress of these diseases, may be explained by considering their functions, without allowing that they take part in the origin and production of disease. Their action is rather that of propagating and disseminating disease than of originating it. The function of the absorbents appears to be confined to the collection of certain fluids, which are without exception returned to the blood; in the chyliferous vessels and lacteals, when the absorbents are highly developed, the fluid absorbed consists of material obtained from the food during the progress of digestion, and fitted for the renewal of the blood; in the extremities and in most of the organs and tissues of the body the lymphatics form an interlacement among the capillaries, and contain a fluid which bears a close resemblance to the liquor sanguinis. As their contents always flow in one direction, and that away from the points of distribution, their function must consist in the removal of material from some one or other source; their function, therefore, is one of collection, and not of distribution for tissue nutriment. The chyliferous vessels and lacteals of the abdomen, which play an important part in the fabrication of certain materials for nutrition, do not immediately distribute these materials to the different tissues, but pour them into the blood, to be by this medium turned to account in nutrition; in like manner the lymphatics collect the superfluous liquor sanguinis, effused through the capillaries for tissue nourishment, and return this to the circulation for distribution. There is no evidence that the absorbents take any active part in the direct supply of material to the tissues, for their renewal or restoration; they rather serve to convey fresh plasma to the blood, obtained from the food through the abdominal absorbents, or to restore through the lymphatics, unused plasma as a provision against unnecessary waste. No chemical action or metamorphosis takes place through their agency, they are only carriers to the blood. Where disintegration of tissue, or other morbid changes take place, the matter thus formed may be taken up and conveyed through the absorbents, and they may thus serve to spread and multiply disease; but that they are in themselves the origin and cause of any of the organic diseases is without proof.

From various points the evidence in support of the part that the capillaries take in the origin of organic disease is strong, and the mineral theory of disease is confirmed.

The mineral theory is based on these grounds: the analytical investigations which tend to show the dual composition of the capillaries; the importance of the inorganic element in their healthy construction; and the deficiency of this inorganic matter, in all diseases of a certain class. The importance of the capillaries in the production of the chemical phenomena of life cannot be over-estimated, as it is solely through their agency, that all the different changes which reduce food to plasma, and furnish the different tissues by exudation with fitting food for repair, take place. The functions of the different organs also depend upon the extreme subdivision of the blood which takes place in the capillaries, and the consequent multiplication of the action of each particular organ on the blood in its passage through the capillaries. In some instances the evidence of the changes that occur in the blood in its passage through the capillaries is well marked and easily recognised. The changes that occur in the blood in its passage through the lungs are evident and clear, and have long since received explanation based on purely chemical causes. In this case the physical changes that occur in the conversion of venous into arterial blood, are so great as to have attracted attention, and to have received satisfactory explanation long since. All these changes are wrought entirely in the capillaries. The changes in the blood that take place in the other organs are not so readily followed, because the physical characters of the blood are not so well marked before its entrance into, and after its exit from the organs, and it is not consequently so easy to divide the blood. Arterial and venous blood carry their characteristic and individual stamp, and it is easy to examine each separately, but the passage of the blood through other organs than the lungs, conveys no such physical change as is evident in lung action. But although the physical changes are not so apparent in other organs as in the lungs, yet in every case the blood, in its passage through any and every organ in a state of activity, receives some impression, or undergoes some alteration dependent upon the function of the organ. Capillary activity is everywhere displayed; and a complete and accurate analysis of the blood, made before and after its passage though an organ, would show this, if it were possible to get specimens for examination, as clearly in the case of the liver, kidneys, &c., as in the lungs.

The capillary system is the main agent through which all the vital changes are wrought, and the existence of phosphates as a constant product of tissue metamorphosis, under all conditions of human life, indicates the activity of the capillaries, and shows that they are especially liable to destruction. Their incessant work calls for continued waste; in health this loss is repaired by reproduction, and a true balance of waste and repair is maintained, but under certain conditions the even balance between supply and demand is disturbed, and capillary degeneration from innutrition sets in. In scurvy, this degeneration has been shown to depend upon deficiency in the food of the inorganic material for capillary nutrition; in rickets the deficiency of bone phosphate for the proper fabrication of the earthy portion of bone has been long recognised; in other diseases there is a marked similarity as to the cause, as shown by deficiency of inorganic matter in the tissues.

Between rickets, scrofula, and consumption, there is evidently a strong band of union. Different members of the same family, with the hereditary taint of struma, show the varieties of these diseases. Every medical man must have seen cases where a family showed different phases of this condition. The young growing child, with softened bones, bending under the weight of the body; an older brother or sister, pale, emaciated, with glandular swellings or enlarged joints, or other scrofulous evidences, and the elder branches afflicted with phthisis. On enquiry, the family history will often show cancer as well as consumption on the side of one or other parent. These cases are too well marked, and of too frequent occurrence to admit of mere accidental occurence, but must depend upon some cause which is at work in all ages. The hereditary taint shows itself in its modifications at all periods of life, and the mineral theory of these diseases affords an explanation of their different forms, by showing them to be dependent upon the laws governing nutrition at different periods of life. To the young child, the chief strain on inorganic nutrition is for bone development, and a deficiency of the proper inorganic aliments of food means the growth of bone without its earthy portion; in later life there is less bone growth, and the disease affects parts which at that period are in full activity. Muscle and flesh are at this period undergoing development, calling into play the full vigour of digestion and its accompanying absorbent system; inorganic deficiency is shown by diminished capillary action, as the symptoms of innutrition testify. When adult life is reached, and bone and muscle no longer require material for increase in growth, but only a sufficiency to supply waste, there is then a tendency for inorganic deficiency to manifest itself in some more local way. The weakest point, or that on which from some or other cause the greatest strain falls, is the first to suffer. In this country, where from climatic influence there is a strain on the lungs, these as a rule are the first to suffer; in tropical regions where the skin takes on a large amount of compensatory action to the lungs, leprosy is a common disease. As life is on the wane, reproduction no longer responds readily to waste; and with altered nutrition, inorganic deficiency assumes yet another form, and cancer in one or other of its varieties occurs.

The graminivora and herbivora are subject to the same kinds of mechanical diseases as man; the different forms of inflammation occur in them as in man, subject only to such variations as the difference in circulation may account for. They also have their zymotic diseases, but when their diseases of nutrition are considered there is a marked difference in the phenomena of these. As long as the herbivora and graminivora are supplied with their natural food, and in proper quantity, the diseases which can be referred to deficiency of inorganic food are unknown. In one of the tables of the Appendix the analysis of the diet of a cavalry horse, fed on the regulation quantity of oats and hay, is shown. A reference to this will show a large preponderance of inorganic matter to heat-producers and flesh-formers, so that if these last exist in proper quantities for health, the former must exist in excess. Herbivora consume in their natural state very large quantities of food, all rich in inorganic matter; so that in these, if the other alimentary principles of food exist, there can be no lack of inorganic material. Under ordinary conditions of fair nutrition, neither the horse nor cow is liable to consumption or cancer. Stall-fed animals, under the combined influence of imperfect hygiene and injudicious feeding, get tubercle; but in these cases it is probable that chemical examination of their food would show deficiency of inorganic matter. The hydro-carbons are here generally given in excess for fattening purposes. Veterinary surgeons of experience have informed me that the only cases of cancer they have met with in either horse or cow, have been in under-fed, ill-conditioned milch cows. In these cases the cause of the disease can be clearly traced to food influence, combined with the requirements of nutrition. In milk the phosphates exist in considerable quantity, and must be derived from the food; under the stimulus of lactation the greater part of the phosphates, which exist in the food enter into milk composition, and the inorganic requirements of the maternal tissues are not attended to. The capillaries are under-fed with inorganic matter, and cancer, as the result of special innutrition, supervenes.

The usual site of pulmonary phthisis, the apex of the lung, is in favour of the theory of its being a disease of capillary origin, depending on nutrition. The activity of the upper portion of the lung is less than the lower, for the bones of the chest at this part form a firm covering which prevent free play. Decrease in activity means diminished nutrition, and any condition arising from impaired nutrition is likely to affect the part which from its weakened condition is least calculated to withstand the effects of imperfect nutrition. Inflammation of the lung generally attacks the lower lobes, for here from greater use there is greater activity, capillary development is more perfect, and the circulation more vigorous; any causes therefore which accelerate the circulation or otherwise interfere with it, are more likely to affect parts in which the circulation is active, than parts which show less vascularity.

The conditions under which cancer occurs strongly support the view of its being a disease of nutrition. It is almost exclusively confined to the declining years of life, coming on only after the culminating point of nutrition is reached, and decay begins gradually to assert its power. The uterus and mamma, which are common seats of the disease, are attacked when their vitality from cessation of their functions has become lessened. Both these structures are capable under stimulus of undergoing great changes, and showing a development dependent upon high vascularity. At other times, when free from the stimulus of gestation or lactation, there must still be a certain latent vascularity, so that influences of nutrition which affect vascular organs, can also influence these structures. In their quiescent state they are subject to the same diseases which affect the capillaries of other structures. Under the healthy influence of gestation or lactation they enjoy freedom from disease, but when this influence is withdrawn there is greater tendency to disease. Women after a certain period of time are more liable to cancer of the uterus or mamma than younger women. In these cases, organs endowed with high vascularity, latent or active, as life advances lose the vitality endowed by activity, and in cases which affect general nutrition, being in a weak feeble state, from inactivity, are the first to suffer.

The microscope to some extent corroborates the views here advocated. In the Lumlican lectures on muscular arterioles, delivered by Dr. George Johnson, attention has been drawn to the general hypertrophy of the muscular walls of the small arterioles in certain forms of disease, especially that form of Bright's disease associated with granular degeneration of the kidneys. This hypertrophy, according to the views here advocated, depends upon, or is coincident with deficiency of inorganic matter in the arterioles or capillaries. Organic diseases have their origin in some disturbance of the laws of nutrition; either there is deficiency of some one alimentary principle in the ingesta, or nerve influence, which controls their conversion into tissue, is at fault. Chemical examination of the different articles of food which compose the dietary of man, shows that in the ordinary diet of man the inorganic portion is that which is most likely to be deficient, or to exist in a form not easily digested or assimilated. In all diseases of nutrition we should therefore expect diseases, which on chemical grounds can be shown to be referable to imperfect mineral supply, to predominate. That this is the case few will deny, if the list be allowed to include all the different varieties of struma, consumption, cancer, and their allied diseases.

Latterly professional opinion has begun to look upon these diseases as much more likely to have some common or allied origin than formerly. Not many years ago they were looked upon as having some specific and perfectly independent cause, but lately these views have been combated, and new light has been thrown upon their points of analogy by more than one observer. Dr. Tibbits and Dr. Simon have both independently shown that there are strong grounds for concluding these diseases to be diseases of innutrition, and Dr. Tibbits has shown the probable relationship of syphilis, scrofula, tubercle, cancer, and other allied morbid conditions. His remarks, based on symptoms and concurrent phenomena, so strongly confirm the views which it is my endeavour to establish, that I quote from his papers in the *Lancet*, of December 23rd and 30th, 1876 :—

"Many now grant that 'tubercle'—*i.e.*, lymphatic overgrowth—is only a variety of scrofula. Wilks considers it a secondary form of scrofula.

"Cancer and tubercle appear to be nearly related, for the following reasons :—(1) They not unfrequently attack members of the same family, but not the same individuals. (2) Cancerous and tubercular peritonitis are in some cases indistinguishable ; so it is with cancer and tubercle of the lymphatic glands. (3) The rare event (related by Paget in his Lectures on Surgical Pathology) of arrest and almost complete recovery from scirrhus of the mamma connected with the evolution of tuberculous disease. Mr. Bryant mentions a case in which he removed a cancerous breast ; the patient recovered with a healthy cicatrix, but died eighteen months afterwards of phthisis. The supposed antagonism between tubercle and cancer may be simply a kind of counter-irritant or derivative action, so that scirrhus of the breast might arrest in this manner the tuberculising process of lung-tissue in its vicinity, or *vice versâ*. Certain it is, in many cases of phthisis, glandular enlargement appears to act as a safety-valve, and thus suppresses, retards, or diminishes the activity of the pulmonary disease. (4) Sir James Paget describes some tumours as mixtures of cancerous and tubercular masses, and he affirms that the microscope will ensure a diagnosis, which appears somewhat doubtful in the present day.

"Primary cancer of the lymphatic glands is not to be distinguished from lymphadenomatous glands. Wilks calls it lymphoid cancer. *Lymphadenoma* in its typical form is said to be general hypertrophy of the lymphatic glands, accompanied usually with enlargement of liver and spleen. Sometimes both are enlarged, sometimes one, sometimes the other, sometimes neither the one nor the other. Trousseau says that in three only out of eleven cases which came under his care was there *any* enlargement of liver or spleen. *Leucocythæmia* is probably the same disease, for, like the former, it may be accompanied with splenic enlargement, when it is called 'splenic,' or with lymphatic glandular enlargement, when it is called 'lymphatic leucocythæmia.' On referring to the variously-named cases, detailed at the Clinical Society of London, on the 24th ult., it appears to me that they differed only in name. I would merely call attention to one or two points. In Dr. Gowers' case we have albuminous urine, hard fibrous or caseating glands, lardaceous degeneration of spleen and caseous infarctions, general lymphatic overgrowth. Dr. Greenfield relates a case of lymphadenoma with an increase in number of white corpuscles; at the same time he says the number of corpuscles (pale) is not large enough for true leucocythæmia. And, further, he thinks this case is not true lymphadenoma; hence he recommends another name for this intermediate disease—viz., 'anæmia lymphatica.' Dr. Goodhart details a case which he suggests may be lymphadenoma, or leucocythæmia splenica, or a mixture of both diseases. Is it not natural to inquire whether there is necessity for so many names in cases so similar? Is the diagnosis of leucocythæmia to rest on the *number* of pale corpuscles in the blood? I would ask, What is the proportion of pale corpuscles to red ones in a normal state? Some authors say one to forty, others say one to four hundred. If there be such a wide difference in what is considered healthy blood, it would be desirable to know the proportion of the pale to the red ones in typical leucocythæmia. Is it no longer typhoid fever because the rose-coloured spots are too numerous, not numerous enough, or altogether absent? Certainly, if new diseases are to be formed on such data as these, a fresh list might be issued daily from all parts of the country. *Addison's disease* is very like the diseases just mentioned, especially as it is frequently connected with tuberculous degeneration of the supra-renal capsules, which are very like lymphatic glands, and abundantly supplied with lymphatics.

"And, further, *tubercle* and *lymphadenoma* must be very intimately associated. In most of Dr. Hodgkin's cases related in the Medical and Chirurgical Society's Transactions for 1832 there was tubercle in lungs, liver, or spleen, and in some of the enlarged glands caseous degeneration had commenced, which Dr. Hodgkin considered a mere coincidence. Caseous degeneration of an enlarged gland has been regarded as a positive proof of the scrofulous nature of the disease, but really it seems to me to be a mark of the great and intimate relationship between scrofula, tubercle, leucocythæmia, and lymphadenoma. Trousseau says that many cases of lymphadenoma seem to arise from, or at any rate follow, long-continued irritation—*e.g.*, ozæna, &c. It is well known that albuminoid infiltration of viscera follows long-continued irritating discharges. I have at the present time under my care in the Bradford Infirmary a girl who has had hip-joint disease for eight years, and who now has immense enlargement of the spleen and liver, great excess of pale corpuscles in the blood, and albuminous urine. Moreover, she has had hæmoptysis and diarrhœa. In the twentieth volume of the Pathological Transactions Dr. Murchison records a case of a man having a phthisical history, in whom, after death, were found enlarged glands, great thickening of the submucous coat of the duodenum (1½in.), tuberculous bodies in the liver and kidneys, and peritonitis. The Committee on Morbid Growths did not venture to give a name to this state of things. In the same volume Dr. Moxon reports a case of lympho-sarcoma of the cervical glands, associated with tubercle in the pleura, and he is obliged to confess that the change was closely allied to, if not identical with, scrofula.

"In syphilis, scrofula, tubercle, and rickets, it is very common to meet with what is known as lardaceous or albuminoid degeneration of the viscera; and sometimes this occurs in leucocythæmia. We are told by Dr. Wilks that the jelly-like translucent material met with in this condition is very nearly allied to that found in colloid cancer, if not in some instances identical with it. Oppolzer calls albuminoid liver colloid liver. Moreover, scrofula and rickets frequently occur in the children of parents who are scrofulous, syphilitic, cancerous, or tuberculous. However, the same morbid conditions sometimes become apparent in the children of very aged or too nearly related parents.

"In studying the pathological histology of these diseases, we do not observe any very markedly distinctive characters in the tissues; indeed, with few exceptions, it is difficult to avoid noticing their general similarity. By the aid of the microscope, two principal forms of structure are revealed—cells and fibres, varying somewhat in size, form, mode of combination, and arrangement. Generally speaking, their diameter is reckoned by thousandths of an inch. The aveolar arrangement of cells is usually supposed to be pathognomonic of cancer, but some of the sarcomata follow the same arrangement. In any case, it is now thoroughly well established that there exists every possible gradation between simple glandular enlargement and cancer of the glands. It is impossible to say where one begins and the other ends.

"It is not easy to see exactly how 'irritation' acts, but in some cases there may be an excessive production of lymphoid cells, retardation, perhaps stagnation, of the current, and disarrangement of the nutritive processes in that part, followed by the same sequence of events in various parts of the body. In other cases the production of epithelial or other cells may be so rapid and extensive that it outstrips the activity of the apparatus for the removal of superfluous and waste material, hence an abnormal growth in that situation; and in other instances there may be a combination of these processes.

"If, then, the essence of these various diseases be a disturbance of the equilibrium between waste and repair, ending in mal-nutrition, to which it must be remembered all these conditions tend, is there not some shadow of foundation for the relationship I have ventured to suggest? It is a matter of observation that plants can be altered to an almost unlimited extent by the character of soil, amount of light, heat, moisture, and by hybridism, and it is equally certain that the habits and characters of animals vary greatly under domestication and other influences. Whatever amount of truth there may be in the theory of Darwin, it is quite evident that by varying the circumstances in all sorts of ways it is possible to produce, at any rate, varieties of species. Although great similarity in the midst of diversity is transmitted from generation to generation, it is quite possible that after some centuries the original peculiarity may be materially altered, or altogether practically removed by dilution. However much we resemble our parents in form, temper, and peculiarities of either body or mind, there is a difference, not only in these points, but, probably, in the viscera, and even in the blood itself. There may be many varieties of corpuscles, both physical and chemical, but which at present we are unable to detect. We cannot but perceive that these little discs are very important agents in nutrition. Is it not possible for a certain condition, or modified condition, of corpuscle to be as easily transmitted from parent to child as a special conformation of the body, or mental peculiarity or imperfection ? Hence it appears probable that the transmutation of syphilis through the generations of four centuries (perhaps many more) should be attended with some transmutation of that complaint. *A priori*, we should expect to see a more marked difference ; but this may be explained by the fact that there are, and probably have been in every generation, numerous fountains from which the virus is continually flowing. Alcoholism, in its transmission through several generations, produces a host of nervous diseases far more dissimilar than those which I have mentioned.

"Are there not innumerable influences ever at work quite sufficient to account, not only for the peculiarities of bodies and minds as they are transmitted from one generation to another, but also for the variations of disease to which they are liable? Let me enumerate some of these influences: Amount, kind, and purity of air, water, light, food, and clothing; temperature, climate, occupation, social condition, habits of life, density of population, stage of civilisation, and nature of soil in locality where the individual resides."

In this paper of Dr. Tibbitt's, the remarks which refer to lymphatic influence, in the production and multiplication of disease, apply with increased force, to the probable influence of capillary action in the production of disease, inasmuch as the active work of nutrition is more dependent upon capillary than absorbent action. When once established in any particular locality, disease may, by absorption of virus, be multiplied and reproduced in other parts, and here the absorbents come into play; but until the original disease has reached a stage approaching disintegration, or produces infecting material capable of absorption, no general infection of the system takes place. Cancer in its first stage is a local disease, and it produces no general disturbance, until the disease has progressed sufficiently to allow of morbid products passing through the absorbents into the circulation. The secondary symptoms depend upon zymotic causes, the original disease upon disturbance in nutrition.

Dr. Simon, in his address delivered at the Midland Medical Society, held in Birmingham, on November 9th, 1877, brought before the notice of the profession the progress that has of late years been made as to the theory and anatomy of cancer. The researches of Mr. Sibley, Mr. Moore, Mr. Campbell de Morgan, and Dr. Simon, show that the so-called cancerous cachexia is the effect and not the cause of cancer, and as regards the anatomy of cancer Dr. Simon says:—

"Of late years, too, there has been change in the point of view in which pathologists have regarded the anatomy of cancer. Thirty years ago, cancer was supposed to be a specific new bodily texture, having (as cartilage or muscle has) an organisation proper to itself in contrast with other textures, and proper to it in all its forms. In those early days of modern histology, not all men who had picked up a smattering of Schwann were competent to understand the real physiological significance of his doctrine: and many a microscopist of those days talked of 'cancer-cells' as he talked of nerve-cells and fat-cells; professing that, by the visible presence or absence of these characteristic cells which he described, every tumour would declare itself malignant or non-malignant. This (in the sense in which it was meant) was an absurd twist to be given to pathology; and I remember that even in 1847, in the first pathological lecture which I gave at St. Thomas's Hospital, I ventured to raise my voice against it. From across the North Sea, however, there was then happily beginning to be heard a voice far stronger than mine; and Virchow, rapidly laying the foundation of his now well-known system of textural pathology, soon consigned to the limbo of vanity those mare's-nest 'cancer-cells' of the too easily satisfied preceding decennium. The profounder and more permanent work which since that time, has been done in the anatomy of cancerous and other tumours, is of really immense amount—immense, even if we regard only the contributions which have been made to it in the German language; but even yet it is far from complete, and the generalisations to which at present it seems to point must of course be deemed subject to correction by further contributions as they come in.

"It is impossible that on this occasion I should attempt to do justice in detail to even any of the more finished sections of that immense anatomical labour; and I will only venture to describe in a few sentences what, up to the present time, seems to me their essential outcome. It seems that cancers have not, as was pretended, any one structure common to them all; that, on the contrary, different species of cancer have structures as dissimilar as the structures of bone and muscle. One principle of similarity does, indeed, apply to them all; not the principle of likeness *per capita*, but the principle of likeness *per stirpes*. Each primary tumour has characters impressed on it, and for the most part very emphatically impressed, by what we may call its particular local parentage. The different species represent different textural origins; each texture which starts a primary cancer having, so to speak, a cancer proper to itself. Mucous and cutaneous surfaces and involutions, connective tissues, pigment tissues, bone and periosteum, muscle-substance, lymph-gland, nerve-substance, and so forth: each has its own distinctive way or ways of growing primary cancer; and as we study the whole range of cancerous tumours, from skirrhus to glioma, we seem to see that the growth of each makes itself only gradually divergent from the normal growth-type of the texture which it represents. And as each sort of primary cancer expresses in this way more or less clearly the organ which started it, so, of course, it is in intimate structural affinity with the non-infective tumours of the same organ; and I believe that the best histologists, when they contemplate the first textural beginnings of a cancer in any affected organ, see only such simple signs of textural overgrowth as might equally be the beginnings of a non-infective tumour.

"In a certain sense, however, though a sense widely different from that of the doctrine of thirty years ago, we may still say that the various sorts of cancer have morphological characters in common; but the likenesses to which I here refer are likenesses rather of expression than of feature. Thus, for instance, it seems general to cancers that the overgrowing textural elements of which they primarily consist do not develop into ripe texture, but remain more or less immature; and that in some cases they exhibit a marked reversion to very early embryonic type. It seems also general to cancerous, as compared with non-cancerous tumours of respectively the same textural parentage, that, as they grow, their first textural type soon becomes obscured: on the one hand, by the crowding of forms which, in proportion as the process is vehement, will more and more be immature or embryonic; and on the other hand by evidences, which are sometimes extreme, of the tendency of the new growth to degeneration. On the whole, then, the knowledge which anatomy hitherto contributes to the explanation of cancer is but indirect, and rather negative than positive in its bearings. The anatomical forms explain nothing in regard of the property of infectiousness which is associated with them, and which, as I will hereafter show, constitutes the real puzzle of the disease. The anatomical forms are matters of mere local accident; but the infectiousness of the cancer represents its very cause."

In support of the mineral theory of organic diseases, the points to which I would draw attention are that in scurvy there is clearly, on chemical evidence, a deficiency in the food of its inorganic alimentary principles, and that the urine affords also evidence of the same deficiency by the scant quantity of phosphatic elements which it yields; both ingesta and egesta bear testimony to the insufficiency of phosphatic inorganic material in nutrition. I have had no opportunity of examining the organs of any patient who has died of scurvy, but there can be no doubt from inductive reasoning, that the capillaries, or the vascular organs, would show a deficiency of tissue phosphate in this disease. In scrofula, consumption, and allied diseases, whenever I have had opportunities of examining the organs of patients who have died of any of these diseases, there has been a very marked deficiency in the quantity of inorganic matter entering into their composition; this deficiency is not confined to the organs principally affected, but pervades the whole system.

As regards cancer, the evidence I have been able to gather is scanty as regards the deficiency of inorganic material; this is in great measure owing to my inability to arrive at any fixed definite inorganic composition of the parts generally affected in this disease; the vascularity of the mamma and uterus are subject to varying influences, and alteration in vascularity would lead to difference in inorganic composition. Unless a standard can be laid down for the inorganic material which a texture in health contains, the alteration caused by disease cannot be recognised. In the case of the organs of high vascularity, and of a certain standard size, the disturbing influences liable to alter the ratio between organic and inorganic material are not nearly so great as in structures likely to be altered by agencies frequently called into play. The healthy lung of the adult retains about the same weight throughout life, but the mamma or uterus of the female varies in size at different periods of life. The mammary gland may get its structure infiltrated with fat; a gland in this condition would show a very different inorganic composition per cent. than a spare gland. Cancer generally occurs at a period of life when there is a natural tendency to fat development; this further complicates the difficulties of analytical examination of tissues likely to become loaded with fat as the mammary gland. The evidence to be gathered in favour of a connecting link between scrofula, consumption, cancer and allied diseases is strong, and has been already partly adduced. This is not merely confined to facts which indicate an hereditary tendency in certain families to exhibit one or other form of the diseases in different members of the same family, but it is no uncommon thing to see tubercular disease follow cancer in the same individual. Several such cases have been recorded, and I believe them to be much more common than their written record shows. On the old doctrines with regard to cancer, all symptoms of disease occurring in other organs subsequent to the recognition of the cancer, were referred to the spread of the disease. *Post mortem* examinations would, I believe, in many of these cases, show true tubercle in existence with cancer, leading to the conclusion that the same error in nutrition which in one organ or texture produces one variety of the disease, in some other texture produces the other variety.

Leprosy is included in the list of diseases of nutrition, depending upon the same causes as those already mentioned, on the supposition that it is true tubercle. The pathological indications present many points of similitude to those of cancer, and tubercle. Local thickening, depending upon capillary block, and subsequent ulceration or disintegration, dependent upon lost vitality, the result of arrested blood supply. In tubercular disease of the lung, the first symptoms are dulness on percussion, and other symptoms showing consolidation, or an impervious condition of the lung tissue; that the mischief originates in the capillaries there is evidence in the similarity of many of the stethescopic signs to those in pneumonia; as the disease progresses, breaking down—*i.e.*, ulceration and disintegration of the part affected take place, and the broken-down portions of the lung get into the air-passages and are coughed up; in cancer of the mamma the first evidence of the onset of the disease is a thickened nodule generally occurring in a vascular portion of the gland, depending, as in the case of tubercular lung, upon capillary obstruction and induration; as the disease progresses similar phenomena of ulceration and disintegration supervene, presenting modifications in effect and in symptoms, which are explicable on the differences which regulate the metamorphosis, arrangement, reproduction and absorption of these different structures. In leprosy the same phenomena of thickening, induration, and subsequent ulceration are to be observed in a highly vascular tissue, the skin. In all these organic diseases, symptoms occur which can be referred to capillary origin, as far as their pathological phenomena indicate, and in all of them the general condition is one that points to some cause of innutrition. Cancer occurs at times in persons of apparently healthy habits, but appearances may be deceptive, and a more careful investigation into the habits and condition of the patient will show that the tissues are flabby, with a tendency to fatty degeneration, or that there has been some debilitating or enervating cause at work. All diseases belonging to this class, whether of the scrofulous, tubercular, cancerous, or leprous variety, affect only highly vascular tissues, or such as have a large proportionate quantity of inorganic matter, as bone. By accepting the mineral theory as applicable to all these diseases, the differences in their character and symptoms follow as consequences of alterations of nutrition, dependent in part upon age, and in part upon climate and constitutional influences. The influences of age upon nutrition are, in all probability, greater than at present recognised; to some extent these are already known, but the alterations in the inorganic constitution of the capillaries at different periods of life has not been made out. Atheroma of, and calcareous deposit in, arteries are well known as morbid conditions of the blood vessels, occurring, as a rule, in advanced life, and doubtless having their origin in innutrition of some form. The concurrent condition of the capillaries in these diseases has not been investigated, but looking at the proof of capillary activity afforded by the urine, and the evidence of their composition yielded by analysis, examination of the ash of the different vascular tissues would show that the capillaries suffer from the same diseases. In these cases the whole vascular system is affected, so that the larger blood vessels give evidence of their altered condition, patent to the ordinary examinations of pathology. The active capillaries, concerned as they are in all processes of nutrition, are of necessity more liable to changes than the larger blood vessels which take a more passive part, acting as mere carriers of blood, When the capillaries alone are the seat of these changes, such changes are only open to the demonstration of analytical chemistry; neither ordinary pathology, nor microscopical evidence can determine these changes.

We know that as age advances the bones become more brittle; this arises from increased quantity of inorganic matter as compared to organic, and may be taken as proof of a change in nutrition of bone, taking place with age, This alteration depends more upon alteration in the quantity of organic than of inorganic matter, for this latter is but little liable to alteration. In adult life the changes of bone take place but slowly; if these changes are sufficient to alter the structure of bone (a tissue but little liable to change under the influence of nutrition), changes altering structure are much more likely to influence the capillaries, which are constantly shredding and renewing both their organic and inorganic matter;

mineral deficiency would therefore in adult life be more likely to affect the capillaries, than bone.

As age alters the phases of these diseases, owing to alterations in nutrition, so also climate and other influences affect them. In any case of innutrition, that organ or tissue upon which the most work is thrown must be the first to suffer. In our humid climate, with its variations of temperature, the lungs are especially liable to attacks of disease. The low average temperature in this country as compared with the temperature of the body, throws great work upon the lungs to maintain the heat of the body. The maintenance of the animal temperature is mainly thrown upon the lungs, and these from their extra work, in cases of innutrition are the first to give way. In hot climates, where the usual atmospheric temperature is near that of the body, and there is consequently but little tax upon the lungs for the maintenance of heat, the skin comes into play as a heat-regulator, and has more active duties than the lungs. In this climate consumption is the prevalent disease of this class; in the tropics, leprosy.

As in cancer, it was formerly the fashion to look upon this disease as having some material and specific cause for its origin; that is, its production by the introduction of a specific infecting medium, by some incrutable, incomprehensible method; so also it was the fashion to look upon tubercle as a deposit originating and causing all the varieties of consumption. In both cases cause and effect were strangely commingled. Cancer is no more the product of a cancer-cell than consumption is the product of tubercle. The views of Dr. Simon have already been quoted for disproving the old views as regards cancer, and will bear application, *ceteris paribus*, to the views as regards tubercle.

As in inflammatory diseases, certain morbid products, as pus, lymph, or serum, are generated, their character being in great measure influenced by the nature of the tissue inflamed; so also in cancer and tubercle, morbid products arise, which vary with the nature of the tissue, which is the seat of disease. In the inflammatory diseases, the chief seat of disease is in the blood, which, by arrest of its regular flow, undergoes changes which furnish these different morbid, humid products. Pus, lymph, and serum present the characteristics of the blood, or some portion of the blood, from whence they originated. These products of disease may present different physical characters from the blood that produced them, but their origin from the blood is beyond doubt. The products of capillary diseases, the result of mineral innutrition, bear in like manner the stamp of the tissue by the disintegration of which they are produced. There are no greater differences in character and appearance between a healthy blood corpuscle and a pus cell, than between a cancerous and epithelial cell. Both the pus cell and the cancer cell are the products of decay, the result of lost vitality; in the one case arising from the separation of some portion of the blood from the healthy circulation—in the other case from the severance of a radicle component of tissue from the influence of nutrition.

The generation of calcareous deposit, as a frequent symptom of tubercular disease, is strongly in support of the mineral theory of consumption and allied diseases. I have not been able to meet with any analysis of these calcareous deposits, nor have I had any opportunity of getting a sufficient quantity for examination; but judging from their general character and appearance, there can be but little doubt that they are associated with some morbid change in the mineral construction of the capillaries. In capillary disintegration of the lungs, the tissue phosphate which enters into capillary composition would be exposed to the action of carbonic acid; as lime is a component part of tissue phosphate, any action which separated the components of tissue phosphate, or rendered it soluble, would, in the presence of carbonic acid, give this acid an opportunity of combining with the lime, to form a gritty, insoluble, carbonate of lime. Or possibly these deposits may consist of bone phosphate, formed by an error of nutrition, leading to a deficiency of the materials, necessary for the formation of tissue phosphate, or depending on their imperfect assimilation. In either case there are materials present in the healthy constitution of the capillaries, which by a disturbance of nutrition, or under the influence of circumstances which would alter the normal affinity of these inorganic bodies, would account for the formation of an insoluble compound, foreign to healthy capillary construction.

The occurrence of this gritty deposit in tubercle, and its absence in cancer, can be accounted for without weakening the theory that they, in common with other diseases of this type, depend upon the same cause—that cause being mineral innutrition. Cancer in many cases is associated with evidences of fatty degeneration, and if even these are wanting as far as outward appearances go, the age of the patient, or the habits of life, lead to the conviction of deficient nutrition. This innutrition generally takes the form of fatty degeneration of the capillaries, with or without concomitant symptoms of general fatty degeneration. In tubercular disease the symptoms point more to defective nutrition, other than that associated with fatty degeneration. The mineral composition of the capillaries shows the existence of a salt of a complex character, in which three or more bases and phosphoric acid take part. Disease originating in the capillaries may depend upon the absence of any one of the mineral elements essential for the formation of tissue phosphate, or upon deficiency of all the mineral constituents. Where the deficiency is confined to a portion of the ingredients, fresh chemical combinations may be formed from the remaining constituents; carbonate of lime and phosphate of lime (bone phosphate) are the compounds most likely to result from this alteration in nutrition. In fatty degeneration there is a deficiency of all the mineral constituents, so that no new compounds result. The calcareous deposits in tubercular disease depend upon the formation of insoluble compounds, resulting from defective chemical action—the defect probably arising from insufficient supply of some portion of the necessary mineral matter for capillary construction; the absence of any such calcareous deposit in cancer may be accounted for by the supposition that the disease in the capillaries assumes more the form of fatty degeneration. In this latter case, the mineral deficiency is complete, and not confined to any single element of mineral capillary composition. A difference in the symptoms of diseases, is no argument against the theory of classification of diseases, based on their origin from some similar cause. The various symptoms and phases of the zymotic diseases do not disprove their dependence upon a common origin, this being an infecting action set up in the blood, and developing phenomena which present very different results. The modifications in the infecting material which produce respectively, scarlet fever, typhoid, or small pox, cannot be made out; but the laws which influence their production and progress show points of similarity, which admit of the classification of these diseases under the zymotic class. Mineral deficiency may be productive of disease which presents as many varieties and modifications as the zymotic cause, without allowing that in either case, the differences in symptoms, indicate distinct and separate diseases without any similarity as to cause.

CHAPTER XIV.

CONSUMPTION.

This disease, in its commonest form, as it affects the lungs, is generally looked upon by the public as a special local disease, in which destruction of the lung is accompanied with certain symptoms, prominent amongst which is loss of flesh, or general wasting. This view is entirely erroneous. The lung disease, as pointed out many years ago by Dr. Latham, and generally accepted in the present day by the medical profession, is no more than a fragment of a great constitutional malady. The changes in tissue that take place, aud the general pathology of the disease, have been to a great extent followed and verified; but the primary cause, or rather the starting point of the disease, has not been defined. My contention is, that in the capillaries we must look for the first radicle changes which produce all the varieties of this disease, and that the defect consists essentially in defective mineral nutrition.

Minute morbid anatomy furnishes but scant evidence of the changes wrought by disease in the capillaries, for the microscopical specimens as at present generally mounted, are put up more with the view of showing cellular change, and the capillaries are lost sight of, or not shown except in irregular and uncertain section. I have tried to get injected specimens which would show the capillary changes in tubercle and cancer, but find great difficulty in getting injected specimens at all, owing to the difficulties which beset their preparation and mounting. Any persevering microscopist would find an interesting field for investigation, in following the capillary changes that occur in organic disease.

The information which the microscope for the present withholds, is however furnished by analytical chemistry and other data. The important functions of the capillaries have been alluded to, and their inferential construction; as also their activity in promoting the different phenomena of nutrition, by the evidence of their metamorphosis, afforded by the inorganic constituents of the urine. If these premises be accepted, it will be seen that the whole symptoms and course of consumption and allied diseases admit of explanation, and that there is promise of success to a rational method of treatment. If consumption can be shown to depend upon mineral deficiency, the supply of the deficient material should in many cases cure the disease. That such a result can in many cases be brought about is beyond doubt, speaking not only from my own limited experience, but on the evidence of cases published by others.

The treatment of disease, particularly where that disease has a progressive character, and shows a tendency, if unchecked or taken in hand only at a late stage, to go from bad to worse, cannot be expected to meet with invariable success. From its very nature, consumption, dependent as it is upon an error of nutrition, cannot admit of treatment by a specific. The disease can never be cured by a few doses of any drug, as ague is cured by quinine. It is essentially a disease of innutrition, brought on by a deficiency of the mineral alimentary element in nutrition; the cause arising from insufficient supply, or from non-assimilation. The rational treatment is the only treatment likely to lead to a successful result; and although a knowledge of the causes which originate the disease must materially help in effecting a cure, yet success cannot be universal. In the treatment of consumption, the capillaries which are the seat of disease, are the main agents on which dependence must be placed to restore lost nutrition. Digestion and assimilation can only take place by means of the capillaries, and if these are so far disorganised as to have lost all power of restitution, the supply of their proper food is useless. A man in the last stage of starvation cannot be restored to life by repletion. If his strength be so far exhausted as to destroy all digestion or assimilation, food is of no avail. Vitality may be reduced to so low an ebb by abstinence, that when food is given its influence can be no longer exerted. The same reasoning which is applicable to starvation is applicable also to consumption. They are but modifications of a condition, presenting many similar features; the one dependent upon lack of all the alimentary principles of food, the other upon the absence of one special alimentary principle (the mineral).

In far advanced cases of consumption, there is another agency which probably exerts considerable influence in preventing recovery. I allude to septic influence. Disease of any kind which leads to disintegration of tissue and brings the effete products of tissue destruction within reach of the absorbents, or of the blood, has a tendency to vitiate the blood. The fatal termination of most cases of cancer can be ascribed to this; and although in most cases of pulmonary consumption septic influence is not so apparent as in cancer, it would be a strange doctrine which allowed that disintegration of tissue, in cases of cancer, prejudicially affects the blood, but that disintegration from tubercle has no such influence. Dr. Lander Lindsay has published, in the *Lancet*, a paper on the "Artificial Production of Human Diseases in the Lower Animals," in which allusion is made to the production of tuberculosis by inoculation. "Bollinger produced tuber-"culosis in the dog by inoculation from man, and in goats "by inoculation from the ox. Professor Villemin, of the "Val de Grace Hospital, Paris, who was the first to show "the transmissabillity of tuberculosis by inoculation in "rabbits and guinea pigs, the matter used being taken "from the human lung, successfully inoculated rabbits "with tubercular matter from the cow; and rabbits with "tubercular matter from each other. His experiments, "or their results, were verified also in guinea pigs; among "others, by Burdon Sanderson and Wilson Fox, who "showed, however, that the same effect could be artificially "produced by inoculation with certain non-tubercular "matter, or even by means of setons." It would be interesting to know the pathological tests used in these experiments for arriving at the conclusions, that true tuberculosis had been produced in these cases by inoculation. During the progress of both cancer and tubercle, tissue disintegration takes place, and the effete matter thus produced may be endowed with septic properties. Secondary cancer shows a difference to the original scirrhus, and soon gives evidence after its appearance that the whole of the current of the blood has become affected. Primary cancer may be removed, and if there be no signs of systemic infection, the subject of the cancer may, in a few instances, be rid of the disease. Secondary cancer holds out no hope of successful treatment by removal. Does not this point to septic influence originating in tissue disintegration, starting from the primary disease? In tuberculosis also, parallel phenomena may exist; in both cancer and tubercle there may be certain secondary conditions, from specific infection, which have been hitherto looked upon as part of the primary disease, because they occur concomitantly, but may nevertheless depend upon absorption and infection. In the experiments quoted by Dr. Lindsay, it is acknowledged that inoculation by non-tubercular matter, or even by seton, produced the same effect as inoculation by tubercle; which certainly tends to confirm the theory that in both cancer and tubercle, after the disease has reached a certain stage—that of disintegration allowing of absorption—septic influences may be brought to bear which give a new feature to the disease.

In their origin, both these diseases in all their forms give evidences of special innutrition, and in their progress give rise to products, endowed like other varieties of septic matter with special influences on living tissue. Pathology affords a parallel instance of the generation of septic matter from tissue, in some cases of acute inflammation, where pyemia ensues from purulent absorption, the result of tissue destruction, and the absorption of the products of disintegration.

In the symptoms, local and general, which characterise these diseases of mineral innutrition, there is evidence that the capillaries are affected in an early stage of disease. The auscultatory signs of a portion of lung rendered solid by ordinary inflammation, or by tubercular disease, are much the same in the early stages of each disease, as far as the stethoscope or percussion can show. The choice of locality for the origin of one or the other disease helps to discriminate between them, as well as other rational symptoms; but as far as the consolidation dependent upon capillary influence is concerned the similarity is well marked. The capillary origin of pneumonia is a recognised clinical fact, but the capillary origin of phthisis has not been made equally clear, and yet often in phthisis the earliest rational symptoms point unmistakeably to the weakened or diseased condition of the arterial system. Copious hemorrhage is at times the first indication of approaching phthisis.

In inflammatory and organic diseases, there is a certain similarity in the symptoms which point to arrested circulation—but the cause differs in the two cases. In inflammatory disease, congestion, the first stage of inflammation, arises from disturbing influences brought to bear immediately on the blood current; in organic disease the disturbance occurs in the walls of the blood vessels. In inflammation which stops short of destruction of the tissue involved, recovery takes place by re-solution. The distended, engorged capillaries, which for the time have been unable to transmit the blood, or to take their wonted part in nutrition, under proper treatment, for the most part directed to the relief of their tension, gradually resume their healthy action. If no effusion has taken place, nor other morbid sequences of the circulatory block have happened, the disturbance arising from mechanical causes is speedily obviated, and with the removal of the cause which impeded the onward, even flow of blood, healthy circulation is restored. In organic diseases, the symptoms depend not upon any acceleration or disturbance in the blood flow, as the primary cause of disease, but upon impaired condition of the blood vessels. The error in nutrition primarily affects the arterioles or capillaries, agents of vital importance in the healthy transmission of blood, and of tissue nourishment and repair. The general emaciation, which as a rule accompanies consumption, shows clearly that the whole system is affected by the disease; there is an agency at work giving rise to symptoms which indicate innutrition, which is not confined to the particular organ or tissue, apparently the seat of disease, but influences the nutrition of the whole body. The external appearances and general condition of a body, when death has occurred from starvation, are so like those presented in cases of tubercular disease, as to afford an opportunity of adducing conflicting medical testimony in favour of one or other view as to the cause of death. In the late Penge case, for instance, analytical examination of the tissues for their mineral constituents would have materially helped in arriving at an opinion as to which of the two conditions caused death. In starvation, the mineral constituents of tissue phosphate would not be materially lessened—from wasting of the tissues caused by the combustion of their organic matter there would be an apparent increase in the per centage proportion of mineral matter; on the other hand, in tubercular disease there would be a material decrease in the mineral matter as compared with the general wasting. In starvation, the soft tissues are quickly burnt up to supply heat, before the capillaries have time to suffer any very material change in their mineral composition; in tuberculosis, the capillaries are the first to suffer. From a deficient supply, or from non-assimilation of mineral matter, the capillaries are underfed and cease to do their work. As in starvation, the combustible material of the tissues is turned to account to keep up temperature, but not until the injury to the capillaries has advanced to such an extent as to leave evidence which can be clearly demonstrated by quantitative analysis. In organic disease, mineral starvation of the arterioles or capillaries is the starting point of the disease, and life ebbs out slowly; in starvation, death ensues directly there is an insufficiency of heat-producers in the blood or the tissues to keep up the normal temperature. Death is more likely to occur rapidly in the one case than the other, because in cases of starvation, unless wilfully and criminally pursued, the cause is recognised and the remedy easily applied; but in organic disease, where the cause has not hitherto been made out, the very treatment adopted may, from error, slowly but surely increase the disease. Accepting the doctrine of the mineral theory of organic disease, the treatment of a patient may, with the best intentions, be carried out with lack of judgment. If merely guided by the general appearance of a patient, his emaciated and weakened condition, the treatment be conducted without any regard to the proper balance of the different alimentary principles of food, a dietary deficient in the one alimentary principle necessary in the case may be chosen. Without recognised principles for guidance, grave errors may be committed; experience soon rectifies to some extent the mischief, and points out some general plan of treatment, laying the foundation for some general empyrical course of treatment for the disease. Has not this been the case as regards consumption in all its different phases ? A short summary of the different methods of treatment will show that the disease has lately met with modifications of treatment, based sometimes on the treatment of symptoms, or an attempt to obviate some of the causes of the disease, such as wasting, or the employment of empirical remedies, the use of which has been prompted by chance or experience.

Cod liver oil, cream, and other foods or medicines rich in the heat-producing element of food, have been largely used in consumption ; and in many cases their use has been attended with considerable improvement in the patient's condition. Doubtless the general emaciation which accompanies tuberculosis, suggested the use of fat-formers. The mineral theory of this disease explains the partially beneficial action of fat-formers as remedial agents. On this theory, capillary weakness, from insufficient renewal of its mineral components, is the first cause of the disease. From their impoverished, under-nourished condition, the capillaries fail to do their work efficiently and thoroughly. Assimilation of food is a portion of capillary work, and if these vessels from imperfect nutrition are partially disabled from work, their work can only be imperfectly done. The work of assimilation goes on but sparingly, and an insufficient quantity of food is, by the process of digestion, rendered available for tissue nourishment and repair, and for the production of heat. In the absence of assimilation of the proper quantities of heat-producing material, the tissues are taxed to keep up normal temperature, the fat is first consumed, and then muscle wastes. The vital heat has to be maintained, and in the absence of a proper supply of fuel from the healthy channels, tissue combustion takes place. The stock in the coal cellar runs low, and the house is pulled to pieces to furnish fuel for the ever-burning human furnace. By supplying an easily-digested heat-producer, cod liver oil exerts a beneficial effect. Digestion which may not be strong enough to appropriate the ordinary carbo-hydrates of food, may yet be able to turn to profitable account cod liver oil. In some cases the temporary relief thus afforded (by easing the work of digestion in one channel, that is as regards the assimilation of the requisite quantity of heat-factors) allows of increased assimilation of the other alimentary principles. With capillaries only able to do a certain amount of work, if a portion of that work be lightened, the remainder of the capillary force available can be turned to other purposes of nutrition. The treatment of consumption by cod liver oil has, however, this objection, that under this plan no attempt is made to treat directly the nutrient error, the cause of the disease. The beneficial effects of cod liver oil for consumption are limited, and its use is restricted, as the number of patients who can continue to take it for any length of time is not great. The alimentary principle which cod liver oil contains is not that which the chemistry of consumption shows to be deficient; the rational treatment indicates the supply of the deficient alimentary principle, and this is the mineral matter for capillary nourishment, and not the heat-factors. If the nutrition of the capillaries be restored, the assimilation of the requisite quantities of heat-producers from the food will follow, as any ordinary diet shows the presence of heat-factors, in sufficient quantities to maintain life. As an aid to nutrition, in conjunction with the requisite mineral matter, cod liver oil can be more successfully used than if given alone.

The phosphorised oils in use mostly contain phosphoric acid; when medicated in this way they possess a slight advantage over cod liver oil in the pure state, but the additional efficacy as tissue or capillary-formers can be but small, for the quantity of acid added is small, and only one factor for the formation of the requsite salt, tissue phosphate, is supplied. Phosphoric acid alone cannot form tissue phosphate, the whole salt should be given, or all the materials for its formation supplied.

The hypophosphites have been largely advocated for the treatment of consumption, and evidence has been borne as to their efficacy in many cases. The cases recorded show, that the use of hypophosphites has been most successful, when given under conditions to utilize the acid and base, as factors of tissue phosphate. Hypophosphorous acid has no place in tissue formation, it is only by conversion into phosphoric acid that it can be utilized. The base with which it is combined, generally lime or soda, can then also take part in the formation of the requsite compound, tissue phosphate. In the *Lancet* of January 20, 1877, is the record of some five or six cases of phthisis successfully treated at Hitchin Infirmary, by hypophosphite of soda, in conjunction with phosphoric acid. In these cases, I have no doubt, that the administration of the free phosphoric acid helped materially towards the cures. By combining hypophosphite of soda with phosphoric acid, the presence of two components of tissue phosphate was ensured, soda and phosphoric acid. Again, in the *Lancet* of July 29th and August 18th, 1876, is a lecture delivered by Dr. Charteris, of Glasgow, illustrating the use of hypophosphites by the record of about thirty cases. In this lecture, Dr. Charteris recommends changing the hypophosphite, giving alternately hypophosphite of soda, and of lime. He has found this more efficacious than keeping to one form of hypophosphate. The explanation of this is easy, if we allow that the destination of each salt is to take part in tissue phosphate formation. Two bases would in this way be made use of instead of one.

Guided by my laboratory investigations, and anxious to test their practical utility, I made a tissue phosphate containing all the mineral ingredients, which analysis has shown the coats of the aorta, and the different organs examined, to contain. With this preparation I have treated successfully some well-marked cases of phthisis, notes of which I append:—

F. L., aged 38, admitted into military hospital at Coventry, on May 22nd, 1877, was a sergeant in the line, but has been invalided for phthisis, as unfit for service.

State on Admission.—Very feeble, unable to walk, cough very troublesome at times, with copious muco-purulent expectoration. Pulse 100, feeble, temperature 101 in the morning, breathing hurried, 35; chest sounds, cavernous breathing under right clavicle, dulness over the whole right lung back and front, with bronchophony and rales. Left side exaggerated, compensatory breathing, night sweats excessive, no diarrhœa, but occasional attacks of ague, which aggravate his cough and increase his expectoration. Weight, 8 stone 7 pounds. To take cod liver oil and iron.

June 18th.—As the treatment had produced no improvement in his condition, he was ordered tissue phosphate three times a day. The quantity ordered contained about one-fourth of the mineral ingredients, that a soldier's daily rations show.

June 28th.—Breathing easier, 28; pulse 86, cough less; continued to improve regularly and steadily, until the date of his discharge on the 4th August.

State at Discharge.—Patches of resonance over the right lung, as if the lung were beginning to heal from different centres. Cough gone, night sweats absent. Is able to take exercise. Weight, 9 stone 4 pounds.

Note on October 24th.—Reported himself to-day being on a visit in the neighbourhood. Has entirely lost his cough, says he feels strong and well, and can endure fatigue without inconvenience. Weight, 9 stone 2 pounds. Chest is resonant on percussion, with healthy but subdued respiratory murmur all over the seat of former dullness and bronchophony. In the following December I saw him in apparently good health, earning a living for himself without inconvenience.

T. B., a soldier on active service in the Artillery, admitted into hospital, August 8th, 1877. Has been twice invalided from India for hepatitis: no previous history of phthisis. For some days prior to admission, had been suffering from rigors in the evening, followed by sweats.

Present state.—Loss of appetite, complexion very sallow, voice hoarse, pulse 105, respiration 38, cough with much purulent expectoration, night sweats. Chest sounds: dullness on percussion over right apex, very marked, coupled with prolonged expiration, and bronchial breathing. Left lung healthy. Clubbing of fingers very marked. To take tissue phosphate, in the same doses as in the former case. Weight, 8 stone 7 lbs.

After two or three days, this man began to improve until the date of his discharge to duty, on the 24th September. At this last date his weight was 10 stone 5 lbs., so that during his six weeks stay in hospital he had gained in weight 26 lbs. At the time of his discharge he was perfectly well and immediately resumed his military duties, which he continued to discharge as long as the battery remained in Coventry, some six or eight months; a good test of his complete recovery, and for all that I know to the contrary, he still doing the hard work of an artillery man.

Lydia S., domestic servant, ætatis 28, came under treatment with tissue phosphate on August 1, 1877. Has been ill for the past three years, with bad morning cough, profuse expectoration, night sweats, and occasional copious hemoptysis. No diarrhœa, but has lost flesh considerably. Dullness over both lungs, but more marked on right side. Bronchial breathing, bronchophony, and râles over both lungs; looks very pale and cachectic. Pulse feeble, 100; respiration feeble and hurried, 35. Weight, 7 stone 4 pounds. From the date of her first attendance she improved slowly but evenly until on the 13th February, 1878, after six months treatment, her chest sounds showed resonance on percussion on both sides, but with subdued breathing on right side; her cough had nearly disappeared, and she appeared fit again for service. At this time she ceased her visits to me, as feeling well; her weight was then 7 stone 12 pounds.

In this last case the patient had taken cod liver oil previously for months at a time without benefit; she came from a poor home, and was stinted in the necessaries of life. These last causes no doubt retarded her recovery. Her catamenia, which when first under my treatment had ceased, gradually returned.

R. W., ætatis, 44, coal carrier by trade, and exposed to all weathers, has had cough at times for the last 9 or 10 years, and for the last six months has got worse, getting about his work with great difficulty. Cough bad, with copious muco-purulent expectoration, at times tinged with blood. Breath short, 40. Night sweats very copious at times. Commenced treatment November 30, 1877. Dullness, prolonged expiration, and crepitution over right lung. Weight, 10 stone. On the 12th of January he was able to resume work, with his chest sounds and rational symptoms much improved, and had increased in weight 12 pounds since he came under treatment.

In these cases the treatment was made to depend upon tissue phosphate alone, as I was anxious to test its efficacy, without using any other remedies.

In mentioning these cases, I do so with no intention of introducing the mineral treatment as a specific for consumption, and its allied diseases, in all their stages, but have simply referred to them in practical illustration of my views. At the same time, I cannot help uttering the conviction that the rational treatment of consumption, based on the mineral theory, will materially decrease the number of unrelieved cases of this disease which at present come under treatment. The treatment by hypophosphites has met with a certain amount of success; on my theory this success depends upon the amount of phosphoric acid and requisite bases that can be turned to account in the formation of tissue phosphate. From its chemical composition, any single hypophosphite can only partially be useful; if we allow that hypophosphorous acid is, at the right time and in the right way, converted into the requisite phosphoric acid—by no means a proven fact—a large proportion of the necessary bases must be deficient. My ideas of treatment extend beyond this, and I propose, by supplying all the mineral ingredients of nutrition, to leave nothing to chance; so that if there be a fair amount of assimilation, all the mineral elements for tissue fabrication, or renewal, may be present. The farmer who calls in the aid of chemistry to enable him to ascertain the deficiencies of his soil for any particular crop, does not, if he expects good results, limit himself to supplying only a portion of the ingredients wanted. He takes care that the manure he uses contains all the mineral matter indicated to be wanted: if he neglect to do this, his success can be but partial, and his crops will fall short for want of some one essential for their growth. The same rules apply to the growth and development of animal life, as apply to the vegetable kingdom, as far as the necessity of certain chemical compounds for their respective growth and development is concerned. Without certain mineral constituents no plant can thrive, and without certain mineral matter no animal can live; in health the requirements of both are fixed and definite, and chemistry can be used to point out their character and quantity.

On the ground of only partial supply of necessary material, can be explained the limited success of the treatment of diseases of nutrition by the means hitherto used. There has been a growing feeling amongst chemists and medical men, that phosphorus or some of its compounds in some way, minister, and are necessary to the healthy maintenance of human life. Phosphorus, and some of its compounds, have been for some time used in medicine; but there is no preparation, either in the British Pharmacopœa, or amongst the medicines in general use, which is capable without the addition of some other ingredient, of forming a tribasic phosphate, such as that found in the tissues.

The Pharmacopœal preparations are phosphorus, and phosphoric acid: in addition to these, phosphates simple and compound, amongst the latter Parrish's solution, are in general use, as well as the hypo-phosphites already alluded to.

As regards the use of phosphorus, I cannot see the advantage or utility of prescribing free phosphorus in preference to phosphoric acid. None of the tissues show the presence of phosphorus. If it only exists as phosphoric acid, why necessitate the oxidation of phosphorus in the system? This process can be far better carried on outside, than inside the body; even when oxidised, as far as capillary nourishment is concerned, it is left to chance to find the proper bases with which to unite to form the requisite salt. As a brain food, phosphoric acid alone, may have its use; as in brain matter there are indications of an excess of this acid: but for capillary use, it can be of no service in the absence of the proper bases.

Does the urine afford evidence of mineral deficiency in cases of organic disease? This is a difficult question to answer, but from investigations which I have been enabled to make I believe that it does. In most cases of these diseases under treatment, the elimination of mineral matter is influenced by diet; and the evidences of the urine must be taken with caution, because the whole of the mineral matter therein found may not result from tissue metamorphosis, but may in part arise from food. Increased animal temperature also produces increased mineral waste, and as there is frequently an increase of temperature in phthisis, the urine may show a larger quantity of mineral matter than that which arises from fair tissue waste. In chronic cases, where the diet has been such as not to influence the phosphates to be found in the urine, I have found a smaller quantity of phosphates than under acute diseases which showed about the same temperature. The only fair and accurate way of arriving at the truth in this matter is by a series of investigations carried on in a public institution, under the necessary supervision of the patients; I have not had an opportunity of deciding the question by such means and on such a scale as to render the evidence conclusive.

The treatment of consumption on the mineral theory has, in the cases I have had an opportunity of attending, been of greater benefit than any other plan of treatment that I have seen adopted; whether it will admit of equally successful application to the earlier stages of cancer remains to be tried. There must be a limit to its success in cancer which falls far short of its limit in consumption. Accepting the theory of their common origin, as the result of mineral capillary innutrition, the site, functions, and method of removal of disintegrated tissue liable in each case to be the seat of disease must materially affect the result. Phthisis generally occurs at a time of life when there is more vitality, and greater power of recovery from diseases, than later on in life when cancer more generally appears. The lost balance of nutrition is more likely to be re-established in youth and early middle life, than in old age; and restoration of nutrition in disorganized tissue to take place, when growth of tissue is in excess of waste. In addition to this, in phthisis the affected tissue is often near to or in contact with some internal or external surface of the body, so that when disintegration takes place there is less risk of septic influences. The muco-purulent expectoration of phthisis pulmonalis sets in at an early stage of the disease; but the ulceration of mammary cancer may not take place, until a late stage of the disease, after there has been deep softening sufficiently advanced to admit of absorption of disintegrated tissue. The power of multiplying and reproducing the disease in other organs of the body, apart from that originally affected, is more quickly developed and more likely to be called into play in cancer than in tubercle, because the broken-down tissue is, in cancer, pent up in the interior of the tissues, and brought more directly under the action of the absorbents. The mineral treatment of organic disease can have no beneficial effect in checking the progress of disease which has reached the stage of blood poisoning, if this has so far altered the nature of the blood as to unfit it for its healthy functions.

In the early stages of cancer, the mineral treatment will probably arrest the progress of the disease, if there be fair assimilative power; and in cases where removal is advisable or admissable, will, it may be reasonably expected, lessen the risk of a return of the disease.

The term capillaries is, everywhere in this work, used in a general sense, and meant to apply to the terminal blood vessels. I have not attempted to assign any distinctive construction in chemical composition to arterioles, capillaries proper, or venous radicles; in referring, therefore, to tissue phosphate as the mineral constituent of capillaries, I do not attempt to limit its precise seat. The arterioles alone may possess this inorganic compound, or its distribution may extend beyond the arterioles. The theory of the deficiency of the mineral aliments in organic disease is not in any way affected by this uncertainty, for its importance as a constituent of the minute circulatory system has been shown.

In bringing forward these views as regards the influence of nutrition in the production of certain diseases, I have confined my remarks as much as possible to such diseases as I believe to depend upon mineral deficiency; where other diseases are mentioned it is to illustrate my arguments, and in the endeavour to render my arguments intelligible. As far as I could I have kept to the original object in view, that of drawing attention to the importance of phosphates in nutrition, and attempting to define their special function. As a short summary of my views, let me draw attention to the following points: for the healthy maintenance of life, food has to fulfil certain conditions, foremost of which stand regulation of temperature, and fabrication or renewal of tissue. For these purposes food must contain certain alimentary principles: these are water, albuminates, or to use a more recent name, colloids, heat-producers, and mineral matter.

For tissue formation the heat-producers are of minor importance to the colloids and mineral matter. Amongst the host of diseases to which human flesh is liable, a certain class are clearly referable to influences of food. All the alimentary principles of food must be present in the daily diet, and for perfect health, their proper balance must be observed. If they be deficient in whole or in part, disease arises which interferes with health, and ultimately, unless the mischief be repaired, ends in death. The deficiency of proximate aliments produces starvation, which may be divided, according to the alimentary principle wanting, into general starvation (absence of all aliment), colloid starvation (fatty degeneration from absence of albuminates), and mineral starvation. It is to this last, whether the cause depend upon deficiency in the food of the proper amount of mineral matter, or upon non-assimilation, that I have endeavoured to draw attention.

In bringing forward these views, which refer the origin of certain organic diseases to capillary innutrition, I have depended mainly upon quantitative analysis, and have arrived at my conclusions for the following reasons: the inorganic chemistry of the tissues shows the presence of tissue phosphate in the arteries, and in all the vascular tissues, and in no other tissues is it to be found: food shows the source of this phosphatic supply; and the urine of man gives evidence of the constant presence of the component parts of this triple salt, evidently as the result of tissue metamorphosis, independently of food influence. In all cases of death from any of the diseases included in the list given, where I have had opportunities of examining the vascular tissues, these showed mineral deficiency, as compared with corresponding healthy tissues. These views, founded on chemistry, are supported by the evidence of the sister sciences; for physiology bears testimony to the importance of capillary action in nutrition, and all organic functions, and pathology shows that the phenomena of organic diseases may originate in the capillaries.

In these expressions there is nothing antagonistic to any proved doctrine; they fit together, and harmonize phenomena which on any other grounds admit of no reasonable or satisfactory explanation.

For such imperfections and shortcomings as exist in the expression of these views, I must plead as an excuse the novelty of the doctrines, and the amount of labour which, single-handed, I have bestowed upon the subject. If the work of others confirms my opinions, a more rational method for the treatment of diseases which have hitherto been looked upon as intractable, and inexplicable, will arise, and my labour will not have been in vain.

APPENDIX.

ANALYTICAL EVIDENCE.

In these investigations the methods of analysis employed were as described.

Lime.—For the determination of this base the best plan is by sulphuric acid and alcohol. Oxalic acid or oxalate of ammonia do not give accurate results in the presence of an acid solution, and if any solution containing phosphates be rendered alkaline, the phosphates are precipitated as well as oxalate of lime.

Method of proceeding: Dissolve the material, after incineration, in dilute hydro-chloric acid and water with heat; filter, and add to filtrate, sulphuric acid dilute, and alcohol. Allow to stand for twelve hours or more, remove precipitate by filtration; ignite at low heat, and weigh residue. Allow for tare of platinum dish and ash of filtering paper, and the remaining weight represents sulphate of lime, 100 parts of which contain 41·17 of lime (CaO).

Magnesia.—This is most accurately obtained in small quantities as ammonio-magnesian phosphate.

Remove lime, as above shown; add two or three small crystals of citric acid, and when these are dissolved, add phosphoric acid and ammonia in excess. Allow twelve or more hours for settlement, then filter, remove, and fire residue. This consists of pyrophosphate of magnesia, which contains 36·33 per cent. of Magnesia (MgO).

The addition of phosphoric acid is preferable to the use of phosphate of soda, as this latter method, in the presence of ammonia, is apt to produce a triple phosphate—not the ammonio-magnesian phosphate, but tissue phosphate, such as I have described in a previous part of this work. Citric acid prevents the formation of this salt, but does not prevent the formation of the ammonio-magnesian phosphate

Potash.—This is to be determined by the ordinary method, as chloro-platinate of potassium. Chloride of platinum is added to the solution, and alcohol to assist the formation of precipitate. In an acid solution this forms slowly and must be allowed time. When formed, remove precipitate on a weighed filter, and dry at 100 c. The precipitate contains 19·31 per cent. potash.

Soda.—Dissolve in hydro-chloric acid, and excess of sulphuric acid. Filter, collecting clear solution in a tared platinum dish. Dry in sand or water bath, until apparent moisture has disappeared, to prevent splashing. Fire at low red heat, until no fumes come off. Weigh capsule and contents. The weight, minus tare, will give all the bases originally present, and sulphuric acid in unknown quantity. To ascertain the quantity of this last, dissolve in hydro-chloric acid and water, and add chloride of barium slightly in excess; filter, fire, and weigh the sulphate of baryta thus removed, and from this estimate the sulphuric acid present. Sulphate of baryta contains 34·33 per cent. of sulphuric acid (SO_3). Deduct the quantity of sulphuric acid from the residue obtained in the first stage of experiment, and the remainder will give total bases. The lime, magnesia, and potash have been already estimated; deduct therefore their weights from the total bases, and the remainder will consist of soda. Sulphuric acid affords the only agent which, in the presence of phosphoric acid, can be depended on for volatilising the phosphoric acid or other acids present. The method of estimation by chloride is incorrect, as hydro-chloric acid does not remove all the phosphoric acid in the presence of phosphates.

Phosphoric Acid.—For this, the determination, as ammonio-magnesian phosphate, will be found to yield accurate and constant results. To ensure the formation of this precipitate, the following method will be found to answer. In the ordinary way of analysing for phosphoric acid, by means of sulphate of magnesia and chloride of ammonium, there is a risk directly the free ammonia is added of obtaining a mixed precipitate consisting of ammonio-magnesian phosphate, tissue phosphate (if soda and potash in any quantity be present), and magnesia. Citric acid has the property of preventing the precipitation of these two last, and allowing only ammonio magnesian phosphate to form slowly but perfectly. If, instead of a solution of sulphate of magnesia and chloride of ammonium, a nearly saturated solution of chloride of magnesium be used, these risks are obviated. Add to the solution to be tested, chloride of magnesium, and a few crystals of citric acid; when these are dissolved add excess of ammonia, and allow twelve hours at least for settlement. Remove, ignite, and weigh precipitate, which will contain 63·67 per cent. of phosphoric acid (PO_5).

Sulphuric Acid.—Chloride of barium gives very accurate results of the quantitative presence of this acid. Add hydro-chloric acid in excess to solution, and then chloride of barium. Boil well together for a few minutes to compact precipitate, which will otherwise pass through the filter, and then strain and collect the precipitate. Fire at low red heat, and estimate sulphuric acid as sulphate of baryta, as given in the directions for estimating soda.

Chlorine.—Estimated by the ordinary volumetric method, by a standard solution of nitrate of silver and yellow chromate of potash.

Sulphur.—Estimated by the quantity of sulphuric acid produced by the oxidation of the material under examination.

ANALYSES OF DIFFERENT TISSUES AND ORGANS FOR INORGANIC MATTER, PARTIAL AND COMPLETE.

Phosphoric Acid in different Healthy Tissues.

Tissue.	*Phosphoric Acid per cent.*
Tendon of Ox	·020
Skin of Pig, undried	·147
Kidney of Pig	·244
Brain of Pig	·589
Lung of Pig	·281
Liver of Pig	·435
Brain of Sheep	·752
Lung of Sheep	·307
Heart of Sheep	·398
Liver of Sheep	·288
Kidney of Sheep	·332
Aorta of Pig (outer coat)	·167
Aorta of Pig (inner coat)	·512
Aorta of Ox (outer coat)	·192
Aorta of Ox (middle coat)	·281
Aorta of Ox (inner coat)	·384
Human Brain (cerebellum)	·723
Human Brain (cerebrum)	·728
Human Lung	·280
Human Kidney	·327

In a case of death from disease of sup. renal capsule the tissues named yielded the annexed quantities of PO_5:—

Tissue.	*Phosphoric Acid per cent.*
Cerebrum	·597
Cerebellum	·482
Kidney	·244
Spleen	·244

In another case, where death arose from a large abscess in one kidney, I found as under in the organs named:—

Tissue.	*Phosphoric Acid per cent*
Spleen	·166
Kidney	·115
Lung	·281
Liver	·140

The kidney examined was not that which contained the abscess, but was pale, flabby, and enlarged. The liver was enlarged and very friable, breaking down on handling. The lungs looked healthy but were much shrunk. The spleen had a very florid appearance. In the former case, where death was preceded by symptoms of cerebal congestion, there was softening of the whole brain, but this was much more marked in the cerebellum than in the cerebrum. The former showed less phosphoric acid than the latter.

Analysis of Human Lung.

Carbonised residue contained.

	per cent.
Lime	·152
Magnesia	·224
Potash	·060
Soda	·034
Phosphoric Acid ..	·280

Chlorine not determined.

Analysis of Human Brain. (cerebrum)

Carbonised residue contained.

	per cent.
Lime	·185
Magnesia	·082
Potash	·197
Soda	·187
Phosphoric Acid ..	·728

Chlorine not determined.

Kidney.

	per cent.
Lime	·045
Phosphoric Acid ..	·327

Cerebellum.

	per cent.
Lime	·050
Phosphoric Acid ..	·723

The last two examinations were not carried further. These tissues were taken from the body of an adult male who broke his neck in a fit of intoxication by an accidental fall. The brain, which was examined about eight hours after death, showed the influence of alcohol. It was as hard as if it had been prepared for examination by being soaked in spirit. The cerebellum showed this more than the cerebrum.

PARTIAL ANALYSIS OF INORGANIC MATTER IN THE TISSUES OF A SOLDIER WHO DIED FROM DISEASE OF SUPRA RENAL CAPSULE.

CEREBELLUM.

	per cent.
Lime	·058
Magnesia	·257
Phosphoric Acid ..	·482

CEREBRUM.

	per cent.
Lime	·053
Magnesia	·114
Phosphoric Acid ..	·599

KIDNEY.

	per cent.
Magnesia	·064
Phosphoric Acid ..	·244

SPLEEN.

	per cent.
Phosphoric Acid ..	·244

The other determinations were not made.

The cerebellum was in this case quite soft. Did not this arise from diminished quantity of phosphoric acid? The healthy brain showed in cerebellum ·723 per cent., and in this case only ·482.

SHEEP'S LUNG (1).

	per cent.
Lime	trace
Magnesia	·032
Soda and Potash	·294
Chlorine	·009
Phosphoric Acid	·300

* SHEEP'S LUNG (2).

	per cent.
Lime	·008
Magnesia	·021
Potash	·180
Soda	·569
Phosphoric Acid ..	·307
Chlorine	·560

* Salt seems to have been added to this, probably by the butcher from whom it was obtained.

Aorta of Pig.—Fibrous Coat.

No. 1.		No. 2.	
Lime	·028	Lime	·016
Magnesia	·026	Magnesia	·046
Potash	·121	Potash	·157
Soda	·130	Soda	·110
Phosphoric Acid ..	·160	Phosphoric Acid ..	·167
Chlorine	·080	Chlorine not determined.	

Aorta of Ox.

Inner Coat.		Fibrous Coat (No. 1).		Fibrous Coat (No. 2).	
Lime	·056	Lime	·020	Lime	·407 (Lime, Magnesia, Potash, Soda together)
Magnesia ..	·093	Magnesia ..	·036	Magnesia ..	
Potash	·231	Potash not detd.		Potash	
Soda	·223	Soda .. ,,		Soda	
Chlorine ..	·150	Chlorine ,,		Chlorine ..	·130
Phospc. Acid	·344	Phospc. Acid	·192	Phospc. Acid	·220

Liver of Young Sheep.

No. 1.		No. 2.	
Lime	·006	Lime	·010
Magnesia	·018	Magnesia	·036
Potash	·113	Potash	·080
Soda	·249	Soda	·180
Chlorine	·100	Chlorine	·080
Phosphoric Acid ..	·288	Phosphoric Acid ..	·256

Kidney of Young Sheep.		Beef (Muscular Fibre.)	
Lime	·016	Lime	·035
Magnesia	·057	Magnesia	·032
Potash	·072	Potash	·190
Soda	·600	Soda	·123
Chlorine	·420	Chlorine	·120
Phosphoric Acid ..	·332	Phosphoric Acid ..	·256

BRAIN OF CALF.

Lime	·095
Magnesia.. ..	·072
Potash and Soda..	·183
Phosphoric Acid..	·665

PIG'S BLOOD.

Lime	·020
Magnesia.. ..	·054
Potash	·260
Soda	·150
Phosphoric Acid..	·115

LUNG OF PIG.

Lime	·024
Magnesia.. ..	·072
Potash	·180
Soda	·346
Phosphoric Acid..	·281
Chlorine	·100

LIVER OF PIG.

Lime	·074
Magnesia.. ..	·108
Potash	·280
Soda	·545
Phosphoric Acid..	·435
Chlorine	·020

ANALYSIS OF HUMAN BLOOD (Becqueril and Rodier).

	Male.	*Female.*
Water	77·900	79·110
Fibrin	·220	·220
Fatty Matters	·160	·162
Serolin	·002	·002
Fat (phosphorised)	·049	·046
Cholesterin	·009	·009
Saponified Fat	·100	·104
Albumin	6·940	7·050
Blood Corpuscles	14·110	12·720
Extractives and Salts ..	·680	·740
Common Salt	·310	·390
Other Soluble Salts	·250	·290
Earthy Phosphates	·033	·035
Iron	·057	·054

The inorganic matter only amounts to ·650 per cent., and of this ·367 is common salt and iron, leaving only ·283 per cent. of other inorganic matter. This is a smaller portion than any vascular tissue contains.

ANALYTICAL EVIDENCE.

SULPHUR IN TISSUES AND IN FLESH-FORMERS OF FOOD.

These examinations were conducted in different ways to ascertain whether phosphorus either in the free state or in any low form of oxidation existed in either tissue or food, and the amount of sulphur contained in both; also whether sulphuric acid was not at times produced by methods of analysis, such as incineration.

The conclusions arrived at are, that phosphorus has no existence in the elementary state, or in any other form than that of phosphoric acid or a phosphate, in either the vegetable or animal kingdom; and that sulphuric acid is at times produced in the laboratory by the oxidation of sulphur, this element being a component part in some way of all nitrogenous animal tissue, and of all the flesh-forming portion of vegetable food. The oxydising agent used was permanganate of potash. The manipulations for the purpose of this investigation are by no means easy, as any one who attempts these experiments will find out, but I have set forth the actual results obtained, and have given explanations to show why I have arrived at these conclusions.

SHEEP'S BRAIN.

Treated for Phosphoric and Sulphuric Acid, and for Phosphorus and Sulphur.

	per cent. PO_5		SO_3
Treated with caustic soda, and then with hydro-chloric acid, strained through linen, and afterwards filtered. Filtrate dried and fired.	·864	..	·06
Boiled with permanganate of potash and fired	·848	..	·153

In these experiments 25 grammes of brain was the quantity operated upon; the actual results obtained were, therefore, in No. 1, ·216 of a gramme; in No. 2, ·212 parts of a gramme of phosphoric acid, showing only a difference quite within the fair limits of manipulation. The yield of phosphoric acid before and after oxidation may therefore be taken to be the same, showing entire absence of phosphorus; but there is clear evidence of the presence of sulphur, for the sulphuric acid in No. 1 was only ·06, and in No. 2, ·153 per cent., showing a difference of ·093, equal to ·037 per cent. of sulphur.

Brain of Calf.

Showing quantities of Phosphoric and Sulphuric Acids, before and after oxidation, as evidence of presence or absence of elementary Phosphorus and Sulphur.

	per cent. PO_5		SO_3
Treated with caustic soda, and hydro-chloric acid — without firing	·662	..	·096
Treated with permanganate and fired	·665	..	·240

In this case, also, only 25 grammes were examined, so that the error is multiplied by showing the result per cent. The filtration or separation of soluble material from brain matter is difficult, as the coagulated albuminous matter is apt to retain appreciable quantities of the solution, even after repeated washing. That the manipulations produced slight error is shown by the fact that in the examination of sheep's brain and of calf's brain, the excess of phosphoric acid is in the first instance in the unoxidised portion, in the second case in the oxidised portion. This experiment shows sulphur in the proportion of ·050 of brain matter examined. A portion of the sulphuric acid obtained in examining the ash of organic nitrogenous substances is probably produced by partial oxidation of the sulphur ever present in these compounds, but the quantity shown in No. 1 of this last experiment could not have been produced in this way, as the solution obtained after treatment with soda and then with hydro-chloric acid, after removal of coagulum, was the portion examined. I have always found sulphuric acid present in small quantities, in the vascular nitrogenous tissues of recently killed animals. I look upon this as evidence of the metamorphosis of tissue going on during life; death taking place before this product of metamorphosis had been eliminated.

Cheese for Phosphorus and Sulphur.

	PO_5	SO_3
Treated with soda and hydro-chloric acid, solution only examined	1·60	·00
Treated with permanganate and fired	1·66	1·05

Milk for Phosphorus and Sulphur.

	PO_5	SO_3
Simply fired ..	·192	·039
Treated with permanganate and fired	·204	·076

Milk for Sulphur (2nd experiment).

	per cent. SO_3
Dried and fired ..	·024
Dried with permanganate, &c.	·075

Beef for Sulphur.

	per cent. SO_3
Calcined simply ..	·040
Calcined with permanganates	·453

Hair for Sulphur.

	Hair from Pad.			Horse Hair.			Human Hair.	
	per cent.			*per cent.*			*per cent.*	
	PO_5	SO_3	..	PO_5	SO_3	..	PO_5	SO_3
No. 1.—Simply calcined	·00	·24	..	·00	·00	..	·00	·00
No 2.—Calcined with permanganate	·00	3·08	..	·00	5·06	..	·00	3·98

Flour for Sulphur.

	per cent. SO_3
No. 1.—Simply fired..	·00
No. 2.—Treated with permanganate	·312

These experiments show that the following substances yield the quantity of sulphur named:—

	Sulphur, per cent.
Cheese	·042
Milk	·014
Milk	·020
Beef	·165
Hair from Pad	1·130
Horse Hair	2·020
Human Hair	1·590
Flour	·122

ANALYTICAL EVIDENCE.

FOOD COMPOSITION.

* TABLE SHOWING THE CHEMICAL VALUE OF DIFFERENT FOODS FOR FEEDING PURPOSES.

PER CENTAGE COMPOSITION OF DIFFERENT FOODS.

	Water.	*Nitrogenous or flesh-forming constituents.*	*Substances fitted to support combustion or lay on fat.*	*Inorganic matter fitted for nutritive purposes and waste.*
Hay ..	16·00 ..	8·16 ..	67·64 ..	8·20
Oats ..	14·20 ..	11·20 ..	67·19 ..	6·60
Peas ..	14·10 ..	23·40 ..	60·00 ..	2·50
Rice ..	13·70 ..	7·80 ..	74·70 ..	3·80
Wheat ..	14·50 ..	14·40 ..	65·20 ..	5·90
Milk (cows)	87·02 ..	4·48 ..	7·90 ..	0·60
Beef ..	72·50 ..	23·50 ..	2·50 ..	1·50
Potatoes ..	75·20 ..	3·60 ..	18·29 ..	2·91
Cabbage ..	93·40 ..	1·75 ..	4·05 ..	0·80
Turnip ..	90·43 ..	1·14 ..	7·81 ..	0·62

For estimating the feeding properties of any article mentioned in this table, the fact of digestibility or the converse must be taken into consideration. This is a matter of experience, and depends upon the assimilative power of the animal or individual,—causes which cannot be tabulated. For showing, however, the general value, for special purposes, of food, the table is of use. The largest quantity of nutritive organic matter is shown in the pea, and the selection of this substance for feeding the German soldier in the late Franco-German War was based on the nutritive value of this food, and the condensed form in which the flesh-forming and heat-giving substances existed.

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* Compiled from different tables, given in "Watts's Dictionary of Chemistry" and the "Cyclopædia of Agriculture."

The value of food is dependent not only upon its organic, but also upon its inorganic constituents. Foremost amongst these is phosphoric acid.

PHOSPHORIC ACID IN FOOD.

	per cent.
Bread	·282
Flour	·330
Beer	·076
Rice	·115
Lemon Juice	·032
Apple	·025
Milk, No. 1	·141
,, No. 2	·083
,, No. 3	·196
Grape Juice	·032
Wine (Madeira)	·064
Cod Liver Oil	·010
Potato, No. 1	·141
,, No. 2	·128
Beef, uncooked	·320
,, ,, No. 2	·353
Salt Beef, from H.M.S. *Hector*	·147
Diabetic Bran Biscuit	·758
Cheese	1·140
Onion	·080
Salt Beef, in soak for one month	·257
Brine from which beef was taken	·707
Hops	1·028
Malt	·450
Liebig's *extractum carnis*	6·455
Coffee, with chicory	·514
Coffee, in berry	·501
Cocoa (nibs)	·990
Tea	·951
Pea (dried split)	·874
Egg (albumen and yolk)	·182

The same results cannot always be obtained in the examination of food, for in many cases the degree of moisture, as in bread, alters the per centage composition, and in others the quality of the article examined affects the results.

I have obtained from the following articles of diet the indicated per centage of inorganic materials :—

POTATO.

Lime	·033
Magnesia ..	·060
Potash ..	·344
Soda	·036
Phospc. Acid	·132

FLOUR.

Lime	·020
Magnesia ..	·042
Potash	·140
Soda	·054
Phospc Acid	·330

BEEF, No. 1.

Lime	·034
Magnesia ..	·033
Potash	·202
Soda	·108
Phospc Acid	·320
Chlorine ..	·100

BEEF, No. 2.

Lime	·035
Magnesia ..	·032
Potash ..	·190
Soda	·123
Phospc. Acid	·256
Chlorine ..	·120
Sulpc. Acid	·040

SALT BEEF,

From the Stores of H.M.S. *Hector*.

Lime	·111
Phospc. Acid	·147

Other determinations not made.

LEMON JUICE.

Lime ..	slight trace
Magnesia ..	trace
Phospc. Acid	·032

Potash and Soda not determined.

MILK, No. 1.

Lime	·086
Magnesia ..	·025
Potash ..	·024
Soda	·102
Phospc. Acid	·145

MILK, No. 2.

Lime	·078
Magnesia ..	·028
Potash	·039
Soda	·465
Phospc. Acid	·196
Sulphc. Acid	·00
Chlorine ..	.150

MILK, No. 3.

Lime	·049
Magnesia ..	·021
Potash } Soda } ..	·161
Phospc. Acid	·083
Chlorine ..	·140

Standard Diet of a Male European Adult, of average height and weight (water free).

	ozs. avoir.		grammes.	
Albuminates.. ..	4·587	..	130	Heat-producers
Fats	2·964	..	84 }	488
Carbo-hydrates ..	14·257	..	404 }	
Salts	1·058	..	30	
Total ..	22·866		648	

Average Daily (water free) Food required for an Adult in very laborious work, or for a Soldier on Service.

	ozs. avoir.		grammes.	
Albuminates.. ..	7·00	..	198	Total
Fats	4·00	..	113 }	Heat producers
Carbo-hydrates ..	17·00	..	482 }	595
Salts	1·50	..	42	

These tables are from Moleschott, as quoted by Dr. Parkes in his work on Practical Hygiene, fourth edition, page 178.

Ration of a Turkish Soldier,

According to *Daily News* correspondent, Oct. 14th, 1877.

Article of Food.		Containing flesh-formers.	Heat producers.
Meat,	256 grammes	60·16 grammes ..	6·40 grammes
Bread,	960 ,, ..	138·24 ,, ..	625·92 ,,
Vegetables,	256 ,, ..	4·48 ,, ..	10·36 ,,
Butter,	4 ,, ..	0·00 ,, ..	4·00 ,,
	Total	202·88	646·68

The bread is calculated as wheat flour, and the meat is reckoned in the raw state, so that a deduction of about 20 per cent. must be made to give the proper proportion of albuminates and hydro-carbons in this diet. With the proper correction this diet would show about 160 grammes flesh-formers, and about 500 grammes heat-producers.

PROXIMATE ALIMENT CONTAINED IN THE DIET TABLE SELECTED FOR EXAMINATION, WHICH IS THE DAILY ALLOWANCE OF A SOLDIER IN MILITARY HOSPITAL ON MIXED DIET, AND REPRESENTS FAIRLY THE AVERAGE DIET OF AN ADULT IN HEALTH.

Avoird. Weight.		grammes.	Flesh-formers.	Heat-factors.
Meat,	12 ozs.	340 ..	79·90 grammes	.. 8·50 grammes
* Bread,	18 ozs.	510 ..	73·44 ,,	.. 332·52 ,,
Potatoes,	16 ozs.	443 ..	15·94 ,,	.. 81·12 ,,
Milk,	6 ozs.	170 ..	7·61 ,,	.. 13·43 ,,
Vegetables,	4 ozs.	113 ..	1·97 ,,	.. 4·52 ,,
			178·86	440·09

* Calculated as flour.

With a deduction of one-fifth for loss in cooking meat, and per centage of water in bread over that in flour, this table shows flesh-formers about 140 grammes and heat-producers 350 grammes.

In the comparison of this table with that of the Turkish soldier, the increased proportion of heat-factors is well marked in the food of the man required to make great exertion and undergo fatigue; for in the one case the dietary of the man at rest shows heat-factors 350 grammes, in the case of the soldier in the field it is necessary to increase this quantity to 500 grammes.

DIET TABLE SELECTED FOR ANALYTICAL EXAMINATION.

Meat	12 oz.
Bread	18 ,,
Potatoes	16 ,,
Barley	1½ ,,
Salt	½ ,,
Tea	¼ ,,
Sugar	1¼ ,,
Milk	6 ,,
Vegetables	4 ,,
Butter	1 ,,
Flour	¼ ,,

Table Showing Inorganic Matter in different principal Articles of Food comprising Diet selected.

Article of Food and quantity in avoird.	Grammes.	Sulphur in Grammes.	Lime in Grammes.	Magnesia in Grammes.	Potash in Grammes.	Soda in Grammes.	Phosphoric Acid in Grammes.	Sulphuric Acid in Grammes.	Chlorine.
Meat (uncooked) 12ozs.	340	·561	·115	·112	·687	·367	1·088	·136	·340
Bread (taken as flour) 18oz	510	·622	·102	·214	·714	·275	1·683	·00	·040
Potatoes (uncooked) 16oz.	443	·096	·146	·266	1·523	·159	·545	trace	trace
Milk 6oz..	170	·034	·146	·042	·041	·173	·246	·00	·210
Vegetables (as cabbage) 4oz.	113	·010	·124	·041	·423	·077	·114	trace	trace
Total ..	1,576	1·323	·633	·675	3·388	1·051	3·676		

The quantity of Sulphuric Acid in food even in the uncooked state is very small; the effect of cooking is to lessen this small quantity, so that practically food may be taken as containing no sulphates. The chlorine also is small, and of this a portion—that existing as chloride of sodium—is removed by boiling. The practice of adding salt to articles of food whilst being cooked, and of eating it at meals, accounts for the general presence of this ingredient in the blood, tissues, and excreta; but only a small portion can be derived from the food itself.

The results given in the preceding table agree with the analytical table published by Dr. Ralfe in his paper on Scurvy, except in the quantity of phosphoric acid, where there is a discrepancy. Dr. Ralfe takes a rather more generous diet than I have done, allowing 24 ozs. of bread instead of 18 ozs., and 8 ozs. of other vegetables, besides potatoes, instead of 4 ozs. In each case the per centage proportion of phosphoric acid is much less in my analyses than in Dr. Ralfe's. This I attribute to the different methods employed for determining this acid. The ordinary methods have in my hands always shown an excess of phosphoric acid, when acting on solutions, which contained quantities of alkalies; these are precipitated partly as tissue phosphate, which is calculated as ammonio-magnesian phosphate, leading to error. The citric acid method is the only plan by which I have obtained constant results on standard solutions of phosphoric acid in the presence of alkalies. The other differences are accounted for, by allowing for the differences in the tables selected.

All foods capable of sustaining animal life show the existence of the same proximate alimentary substances, flesh-formers or albuminates, heat-producers or hydro-carbons, and inorganic salines. The different grasses which furnish food for herbivora, and the grain and dried food for graminivora, can all be shown to contain these proximate principles.

The regulation allowance for a cavalry horse is 10 lbs. of oats and 12 lbs. of hay per day. The per centage of feeding matter in each is in

	Oats.	Hay.
Flesh-formers	13·60 ...	81 60
Heat-producers	55·50 ...	67·40
Inorganic matter	3·80 ..	8·20

A pound equals about 450 grammes; the daily allowance will therefore show:—

	Oats.	Hay.
Flesh-formers..	642·0 grammes ..	440·64 grammes
Heat-producers.	2497·5 ,, ..	3639·60 ,,
Inorganic matter	171·0 ,, ..	442·80 ,,

A total of flesh-formers in round numbers of 1050 grammes, and of heat-producers of 6000 grammes.

The ordinary diet of man shows about 150 grammes of flesh-formers, and 500 of heat-producers; the cavalry horse therefore consumes 7 times the quantity of flesh-formers, and 12 times the quantity of heat-producers required for his rider.

Both heat-producers and mineral matter predominate in the dietary of graminivora.

Analyses of the ash of oats and hay show the following proportions of the chief nutritive inorganic materials. (Article Ash, "Cyclopædia of Agriculture"):—

Ash of Oats.	per cent.	Ash of Hay	per cent.
Lime	3·92	Lime	12·89
Magnesia ..	7·70	Magnesia ..	3·42
Potash	17·76	Potash	3·79
Soda	2·49	Soda .. .. }	5·40
Salt	0·20	Salt .. .. }	
Phosphoric Acid	18·19	Phosphoric Acid	4·37

Oats yield about 3 per cent. of Ash, and Hay 7·50 per cent.

10 Lbs. of Oats and 12 Lbs. of Hay would show—

	Total in grammes.
Lime	57·
Magnesia	24·
Potash	40·
Soda	3·
Phosphoric Acid	40·
Total ..	164·

If the phosphoric acid be taken as the chief factor in tissue phosphate, and as an indication of the amount of this salt that can be assimilated for purposes of nutrition, it is obvious that the food of graminivora contains a larger proportion of inorganic material for nutrient purposes than the food of man. This table shows 40 grammes of phosphoric acid, while the diet table of man which has been examined shows only 3·67 grammes.

Herbivora, in the natural state, consume large quantities of food rich in inorganic matter, and under these circumstances, run no risk of disease arising from causes dependent upon deficiency of inorganic nutrient matter.

ANALYTICAL EVIDENCE.

According to Berzelius, human *fœces* contain :—

Water	73·000
Insol. animal and vegetable matter	7·000
Mucus, fatty matter, &c.	14·000
Bile	0·900
Albumin	0·900
Extractive matter	2·700
Chloride of Sodium	·309
Sulphate of soda	·155
Carbonate of soda	··271
Phosphate of magnesia	·155
Phosphate of lime	·310
	100·000

Per centage of ash, 1·200

ANALYTICAL EVIDENCE,

URINE.

ANALYSIS OF URINE PASSED IN 24 HOURS BY A HEALTHY ADULT ON MIXED ORDINARY DIET.

Quantity passed—1496 C.C.

	grammes.
Lime	·495
Magnesia..	·674
Potash	2·020
Soda	4·830
Phosphoric Acid	1·728
Chlorine	6·300
Sulphuric Acid	not detd.

The second analysis of the urine of the same individual on another occasion, under apparently the same conditions of health, showed—

Lime	·855
Magnesia	·300
Potash	·750
Soda	4·815
Chlorine	4·500
Phosphoric Acid	2·880
Sulphuric Acid	3·135

The urine of a patient suffering from tubercular disease of lung and abdominal glands showed in 24 hours.

Lime	·392
Magnesia..	·234
Potash and Soda	4·110
Phosphoric Acid	1·302
Chlorine	2·520
Sulphuric Acid	1·452

Comparative quantities of phosphoric and sulphuric acids in urine.

No. 1.—Healthy adult in 24 hours.

	grammes.
Phosphoric Acid	2·954
Sulphuric Acid	3·122

No. 2.—The same. on another occasion.

Phosphoric Acid	2·880
Sulphuric Acid	3·135

No. 3.—Soldier in Hospital on Milk Diet and extras.

Phosphoric Acid	2·820
Sulphuric Acid	1·276

No. 4.—Soldier in Hospital on Milk Diet alone.

Phosphoric Acid	5·100
Sulphuric Acid	2·652

No. 5.—Case of Phthisis in last stage, accompanied with albuminuria.

Phosphoric Acid	2·176
Sulphuric Acid	2·686

This man was much reduced by disease, and was taking very little food. The amount of sulphuric acid showed, therefore, large tissue consumption without equivalent reproduction.

*No. 6.—Case of Phthisis treated with Phosphates.

Phosphoric Acid	4·99
Sulphuric Acid	2·76

* The excess of phosphoric acid in this case, evidently depended upon the medicine. The rapid appearance of phosphates in the urine, in excess, showed non-assimilation, leading to unfavourable prognosis. Death occurred about three months after.

Experiments to show the action of ammonia in precipitating tissue phosphate, that is, tribasic phosphate, analogous in chemical composition, as far as its tribasic character is concerned, to tricalcic, and to ammonio-magnesian phosphates, but differing from both in the nature of the bases, and in its properties.

No. 1.—HEALTHY URINE, SHOWED *per cent.*

	Before treatment with ammonia.	After treatment with H_3N. and filtration.	Matter Removed.	Theor. quantity of PO_5 required to form tissue phosphate.
Lime	·070 ..	·00 ..	·070 ..	·060
Magnesia	·036 ..	·021 ..	·015 ..	·011
Potash and Soda ..	·656 ..	·595 ..	·061 ..	·030
Phosphoric Acid ..	·243 ..	·153 ..	·090	——
Chlorine	·520 ..	·520 ..	·00	Total ·101
Sulphuric Acid ..	·220 ..	·220 ..	·00	

The estimated quantity of phosphoric acid disagrees in this experiment with the theoretical quantity by ·011 per cent.

(2.) A portion of the same urine as No. 1, but treated with a little carbonate of lime, and filtered before the addition of H_3N.

	Before treatment.	After treatment.	Removed.	Theoretical quantity of PO_5.
Lime	·070 ..	·00 ..	·070 ..	·060
Magnesia	·036 ..	·006 ..	·030 ..	·022
Potash and Soda ..	·656 ..	·564 ..	·092 ..	·046
Phosphoric Acid ..	·243 ..	·115 ..	·128	——
Chlorine	·520 ..	·520 ..	·00	Total ·128
Sulphuric Acid ..	·220 ..	·192 ..	*·028	

* Removed as sulphate of lime.

The removal of a small portion of sulphuric acid in the second experiment increased the precipitate of tissue phosphate. The actual and theoretical quantities of phosphoric acid are the same, being ·128 per cent.

No. 3.—Examined healthy urine quantitatively for sulphuric acid. Took half a litre, and by means of a standard solution of chloride of barium, removed all the sulphuric acid. Filtered, treated filtrate with excess of liquor ammoniæ, and allowed 12 hours for precipitation. Filtered and dried precipitate.

Urine contained before Treatment with Ammonia

Phosphoric Acid .. .. 1·150 grammes.

After removal of precipitate

Phosphoric Acid .. .. ·285 grammes.

The total weight of dried precipitate was 2·96 grammes, which contained in 1 gramme—

			Theor. PO_5.
Lime	·214 grammes	.. ..	·180
Magnesia ..	·074 ,,	.. ..	·054
Potash	·208 ,,	.. ..	·104
Sodium Chloride..	·068 ,,		
Phosphoric Acid ..	·332 ,,	Theorl...	·338
Organic matter, &c., adhering to precip.	·098		

The synthesis of this would be—

Lime	·214	Tissue phosphate. ·834
Magnesia ..	·074	
Potash	·208	
Phosphoric Acid..	·338	
Chloride of Sodium		·068
Organic Matter, &c.		·098
		1·000

The quantity of precipitate obtained, and its composition, show that there was an excess of phosphoric acid, uncombined; amounting in the 500 c.c., taken to nearly ·300 parts of a gramme. If the syntheses of the other analyses of urine given, be taken in the same way, the same results will be shown.

In my analyses already given, at page XXII. of Appendix, the bases in combination with phosphoric acid, and phosphoric acid itself, will be, in

No. 1.		PO_5 in combn.	No. 2.		PO_5 in combn.
Lime ..	·495 ..	·418	Lime ..	·855 ..	.722
Magnesia	·674 ..	·498	Magnesia	·300 ..	·221
Potash	1·173 ..	·590	Potash ..	·750 ..	·377
			Soda ..	·885 ..	·675
		1·506			1·995
PO_5 obtained		1·728	PO_5 obtained		2·880
,, theor. combd.		1·506	,, theor. combd.		1·995
PO_5 in excess		0·222	PO_5 in excess		0·885

In Dr. Miller's analysis, as quoted in Todd and Bowman's "Physiology"—

	In 1000 c.c. of urine.	PO_5 theor. comb.
Lime	210	.. .. .. ·176
Magnesia	·120	.. .. .. ·008
Potash	1·930	.. .. .. ·972
Soda	·050	.. .. .. ·038
		1·194
	PO_5 obtained ..	2·120
	,, theor. combd.	1·194
	PO_5 in excess ..	·920

ANALYTICAL EVIDENCE.

ANALYSIS OF THREE SAMPLES OF TISSUE PHOSPHATE, PREPARED IN LABORATORY.

No. 1. (Dried.)

	Fractions omitted.
Lime	30
Magnesia	9
Soda	16
PO_5	44
Loss	1
	100

No. 2. (Dried.)

Iron	2
Magnesia	18
Lime	10
Soda	25
PO_5	42
Loss, &c.	3
	100

No. 3. (Only partially dried.)

Lime	8
Magnesia	21
Potash..	22
PO_5	32
Moisture, &c.	17
	100

Prepared from alkaline chlorides, and phosphates—shows that different proportions of each base may enter into tho composition of this precipitate.

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